

UPSALA COLLEGE LIBRARY
East Orange, NJ 07019
JUL 22 1985

DÆDALUS

JOURNAL OF THE AMERICAN
ACADEMY OF ARTS AND SCIENCES



Weapons in Space

Vol. I: Concepts and Technologies

Hans A. Bethe
Jeffrey Boutwell
Ashton B. Carter
Alexander Flax
Richard L. Garwin
Kurt Gottfried
Donald L. Hafner

Richard Ned Lebow
F.A. Long
Paul Stares
Gerold Yonas
Herbert F. York
Charles A. Zraket

SPRING 1985

LICENSED TO UNZ.ORG
ELECTRONIC REPRODUCTION PROHIBITED

\$5.00

BOARD OF EDITORS:

David Apter, Daniel Bell, Isaiah Berlin, François Bourricaud,
Herman Feshbach, Paul Freund, Clifford Geertz, Gerald Holton,
Charles P. Kindleberger, Hans H. Landsberg, Martin Meyerson,
Steven Muller, Carl E. Schorske, Judith N. Shklar, Jean
Starobinski, Lewis Thomas, Robert Wilson

STEPHEN R. GRAUBARD
Editor of the Academy and of Dædalus

ELIZABETH LILLA
Manuscript Editor

CAROLYN W. ERSKINE
Editorial Assistant

MARTHA H. NELSON
Editorial Assistant

DÆDALUS

JOURNAL OF THE AMERICAN ACADEMY OF ARTS AND SCIENCES

Weapons in Space vol. I: Concepts and Technologies

Spring 1985

Issued as VOLUME 114, NUMBER 2, of the Proceedings
of the American Academy of Arts and Sciences





Spring 1985: Weapons in Space, vol. 1. Issued as Volume 114, Number 2, of the Proceedings of the American Academy of Arts and Sciences

Copyright © 1985 by the American Academy of Arts and Sciences

Library of Congress Catalog Card Number 12-30299

Editorial Offices: Dædalus, Norton's Woods, 136 Irving Street, Cambridge, Massachusetts 02138

Dædalus (ISSN 0011-5266) is published quarterly by the American Academy of Arts and Sciences. Subscription rate: \$16, one year; \$32.00, three years.

All subscriptions and single copy orders and change of address information must be sent in writing to the Dædalus Business Office, P.O. Box 515, Canton, Massachusetts 02021, U.S.A. (Tel) 617-828-8450. Orders for single copies must be accompanied with prepayment of \$5.00.

*Printed in the United States of America
Printing Office: 2901 Byrdhill Road, Richmond,
Virginia*

Second-class postage paid at Canton, Massachusetts, and at additional mailing offices.

Contents, vol. I

v	Preface
	F.A. Long
9	Foreword
15	Glossary of Acronyms
	Herbert F. York
17	Nuclear Deterrence and the Military Uses of Space
	Alexander Flax
33	Ballistic Missile Defense: Concepts and History
	Hans A. Bethe, Jeffrey Boutwell, Richard L. Garwin
53	BMD Technologies and Concepts in the 1980s
	Gerold Yonas
73	The Strategic Defense Initiative
	Donald L. Hafner
91	Assessing the President's Vision: The Fletcher, Miller, and Hoffman Panels
	Charles A. Zraket
109	Strategic Defense: A Systems Perspective
	Paul Stares
127	U.S. and Soviet Military Space Programs: A Comparative Assessment
	Kurt Gottfried and Richard Ned Lebow
147	Anti-Satellite Weapons: Weighing the Risks

	Ashton B. Carter
171	The Relationship of ASAT and BMD Systems
190	Notes on Contributors

ADVISORY GROUP

Ruth Adams, Jeffrey Boutwell, Harvey Brooks, Ashton B. Carter, Abram Chayes, Herman Feshbach, Alexander Flax, Richard L. Garwin, Donald L. Hafner, Spurgeon Keeny, F.A. Long, Judith Reppy, Jack Ruina, Walter Slocombe, Jasper Welch, Jr., Charles A. Zraket

Preface to the Issue, “Weapons in Space,” vol. I

IT IS EXACTLY TWENTY-FIVE YEARS since *Daedalus* first began to publish on American military policy and the prospects for arms control. Jerome B. Wiesner, writing the Foreword to the special issue on arms control that appeared in the fall of 1960, spoke of the necessity “to provide some of the basic information and understanding needed for an intelligent public discussion of the disarmament problem.” Wiesner expected the dialogue to be long and difficult; he and others believed that a journal like *Daedalus* could make its major contribution by setting down certain incontrovertible facts, and at the same time inviting commentary and analysis from those whose expert knowledge might be expected to weigh with individuals seeking to understand the new problems created by atomic arms. The mood of 1960 was reflected in the expectation that the dialogue would contribute to the quest for a lasting peace, that it might create a world more committed to disarmament.

This initial study of arms control in *Daedalus* had many good effects. First, it suggested something of the complexity of the problems—technological, political, strategic, and diplomatic—that were even then beginning to preoccupy those who had any knowledge of the subject. Second, it helped to explain why able and thoughtful people might reasonably disagree on major issues of national security. Technology, it was realized, mattered enormously; so, also, did the changing relations between the Soviets and the Americans, and the different emphases each gave to negotiations, military security, and internal politics. In the twenty-five years after the publication of the first *Daedalus* issue, events moved so rapidly technologically and conceptually that early policies constantly had to be reviewed and

modified. In this climate, peace, at least between the superpowers, was maintained. This was certainly the most remarkable achievement of the first four post-World War II decades. How atomic terror came to be contained during these years will be a subject for historical study for many generations.

The question today is whether those changes in strategy now contemplated are likely to have the same effect. In publishing this issue on "Weapons in Space," *Dædalus* pursues its policy of posing questions fundamental to any consideration of war and peace prospects in the contemporary world. This, however, is more than a study of the political conditions that now exist in the continuing military rivalry between the Soviet Union, the United States, and their respective allies. It has to do principally with the question of how the United States now proposes to defend itself, how novel strategic defenses, presuming they are indeed constructed, may influence the Soviet Union, America's allies, and others. Given what is now contemplated, every kind of military force, conventional or nuclear, could be affected. If President Reagan's Strategic Defense Initiative is successful, the new technologies herald more than a change in American military strategy; they are intended to create new invulnerabilities, and, by definition, new vulnerabilities. Those who favor the program assume that the advantages will accrue principally to those who have initiated it, the Americans; those who question the new proposals see only the prospect of exacerbated and destabilizing military and other competition between the U.S. and the USSR.

These proposals come at a time when traditional doctrines of deterrence are criticized, both at home and abroad, by political forces on both the Left and the Right. They come also at a time when the American economy appears to be booming; when the Soviets, by comparison, are confronting major economic difficulties. Whether either condition is likely to endure for very long, and how such massive programs of military development are likely to affect them is all too rarely asked.

The even more imperative need may be for new reflection on what is likely to happen in the coming period of experimentation: how the Strategic Defense Initiative is likely to be politically and militarily justified; how it will affect America's relations with the Soviet Union and its own allies; what it may, in time, incite the Soviets to do; how it is likely to influence their defensive and offensive military planning;

and what diplomatic and political initiatives it may spawn. More than that, it raises an even more fundamental question—whether a world increasingly armed, in a way now proposed, will in time be a more secure world for both the United States and its friends, or whether it will serve principally to create new alarms, with new hazards to the security of all, including the United States. If the answer to that question were as obvious as some believe, there would be no need for further dialogue.

To try to comprehend what is now in prospect, to reflect with sobriety and judgment on the implications of what is being set in motion, will require new voices, trained in international security matters, to join the “veteran” analysts of the 1950s, 1960s, and 1970s in developing accurate information, reasonable hypotheses, and persuasive criticism of public policy. So long as the problems are seen as primarily technological, or, alternatively, wholly political; so long as proposals are dismissed as being simply economically unfeasible, there will be powerful incentives for others to argue the contrary. Since nothing succeeds in the twentieth century so much as rhetoric, the possibilities of a rational and calm discussion are necessarily limited. Still, facts do intrude; in the long run, many voices, both at home and abroad, are likely to be heard. The need today is to create a climate that acknowledges the force of contingency, and encourages a critical dialogue, with some historical and moral understanding. These *Daedalus* volumes are intended to open a debate, not to close it.

Thanks are due to the Carnegie Corporation for funds made available to the American Academy of Arts and Sciences that, in turn, permitted the journal of the academy, *Daedalus*, to publish these volumes. A special debt is owed to Professor Franklin Long, chairman of the Academy’s Committee on International Security Studies; he helped initiate the project, and saw it through. He, together with Drs. Jeffrey Boutwell and Donald Hafner, contributed greatly by working closely with many of the authors. It is entirely appropriate that these volumes should contain the reflections of some who may be thought of as the “veterans” of defense policy analysis, together with the insights of a new generation now appearing on the scene, of whom much is expected and a great deal will be demanded.

S.R.G.

Foreword

IN HIS 1983 “Star Wars” speech, President Reagan set a major new goal for the United States in its efforts to avoid nuclear war. The U.S. military, with the aid of the nation’s scientists, was to study the science and technology of defense against nuclear weapons so that America could ultimately develop and deploy a defense so totally effective that nuclear weapons would be rendered “impotent and obsolete.” As a first step, the Department of Defense established a large new program, the Strategic Defense Initiative (SDI), to manage and support a greatly expanded research effort into nationwide defenses.

The fundamental question underlying this effort is how best to avoid nuclear destruction. The Soviet Union, confronted with the U.S. nuclear arsenal, faces the same problem, and arms negotiations between the two nations have long been based on a perceived mutual interest in avoiding war. The immense destructiveness of nuclear weapons contributes directly to the continuing mutual deterrence against their use. This deterrence stems from the recognition by the two superpowers that even a surprise first strike will not prevent the nation being attacked from launching a devastating retaliatory strike: destruction will be mutual. What makes the “Star Wars” proposal so dramatic is that it calls for the U.S. to move away from retaliatory nuclear deterrence (or mutual assured destruction, as it is sometimes called) by building fully effective defenses against nuclear weapons. This change in strategy by the U.S., of course, leaves open the question of Soviet military and political responses.

This is not the first time that the U.S. and USSR have each been actively involved in developing and deploying defenses against nuclear weapons. The first was in the mid-1960s, and the difference between then and now is instructive. Then, as now, there were strong advocates for deploying defenses against nuclear-armed ballistic missiles. Then, as now, both nations were engaged in vigorous research and development programs for defensive systems. However, there were serious doubts in the U.S. concerning the strategic implications of the proposed defenses. And detailed cost analyses conducted by the Pentagon concluded that deploying missile defenses was not cost-effective against obvious possible Soviet responses. In the end, although both nations deployed limited defensive systems, the two nations agreed to negotiate to ban such systems. The result was the bilateral Anti-Ballistic Missile Treaty of 1972, which set severe mutual restrictions on the development, testing, and deployment of ABM systems. The treaty remains in effect, and is a factor in current discussions about the SDI.

Although defense against nuclear attack is one of the items being considered in the current arms-control talks between the U.S. and the Soviet Union, their negotiating positions appear to be far apart. The aim of the Soviets seems to be to stop the expanded U.S. research program, and the aim of the American negotiators seems to be to maintain the SDI as a major U.S. effort. The most likely outcome is agreement to disagree: this would leave the U.S. free to proceed with the Strategic Defense Initiative and related programs, and the Soviet Union free to respond as it sees fit. The likelihood and character of Soviet responses will, of course, greatly influence the feasibility and costs of the U.S. program, and as Paul Nitze recently noted, the projected defenses will need to be both cost-effective and survivable, even in the face of major Soviet responses.

A complicating aspect of the SDI is that many of the most interesting new technologies are designed to be deployed in space, on earth-orbiting satellites—some as sensors, others as weapons. However, many of these new technologies are only in the very early stages of study; hence, it will be many years before enough is known to permit a decision to deploy them, and even then the ultimate success of the overall defense system will be far from certain. This uncertainty will stem partly from doubts about systems capabilities and reliability, and partly from concern about possible Soviet counter-

measures such as reducing the vulnerability and increasing the numbers and penetrability of their nuclear weapons.

Until there is high confidence that the new defensive systems are impregnable, the U.S. will be quite unwilling to abandon its reliance on retaliatory deterrence based on large offensive forces. This raises the prospect of a complex offensive and defensive arms competition between the U.S. and Soviet Union that could continue for years, if not decades. A combination of large military expenditures and great political uncertainty will have an unsettling effect on American domestic politics and U.S. relations with its allies, and one can assume that debates on strategic defenses will continue and intensify.

The contributors to this volume have attempted to deal constructively with the principal issues raised by the SDI. They give a broad picture of the weapons that are being proposed for use in space, and assess their opportunities and problems. They offer arguments for and against U.S. deployment of defensive weapons systems, and in so doing raise political as well as military and technical concerns.

Following the introductory chapter by Herbert York, which examines U.S. and Soviet military space activities in the postwar period, there is a general consideration of the problem of defense against land- and sea-based ballistic missiles. ICBMs and SLBMs represent the major current threat to the U.S., and the Strategic Defense Initiative is therefore concentrating its research on ballistic missile defense (BMD). Since the travel times for the warheads launched by these missiles is in the range of ten to thirty minutes, a major problem confronting a defense system is how to respond reliably and promptly to a major missile attack. Thus any BMD system that is developed will have to be both technically feasible and coordinated by an effective and reliable command-and-control system. Analyses of previous BMD efforts and the current SDI are provided by Alexander Flax, Gerold Yonas, Donald Hafner, and Charles Zraket.

Because Soviet missiles are deployed either in underground silos deep within the USSR or on submarines in the open ocean, it is essential for the defense to use space-based systems, i.e., orbiting satellites, for launch detection, tracking, and eventual attack on the missile or its warheads. It is highly desirable to destroy missiles at launch before they have deployed their multiple warheads, but because the earth is round, the launch sites distant, and the time for attack short, a successful attack at launch must come from space,

preferably using kill mechanisms that travel at or near the speed of light. Major research and development, however, will be required to identify likely kill mechanisms and determine their effectiveness, their probable costs, and their vulnerability to countermeasures. An extended analysis of these prospects and problems is provided by Hans A. Bethe and Richard L. Garwin in the technical appendix to this collection; a paper by Bethe, Garwin, and Jeffrey Boutwell summarizes these analyses from a somewhat less technical point of view.

Three articles in this collection deal with the anti-satellite weapons (ASATs) that may be deployed by the U.S. and the Soviet Union, and that may seriously complicate development of an effective defense against nuclear weapons. Weapons for use against satellites can be ground-based, air-based, or space-based and their task is relatively uncomplicated, given that satellites are relatively fragile and travel in predictable orbits. The Soviets have tested and deployed a comparatively simple space-based ASAT, and the U.S., which in the 1960s deployed a ground-based system and then abandoned it, is now developing more advanced ASAT systems. Although the objectives and difficulties of space-based systems for ASAT and for BMD are quite different, there is or can be considerable technical overlap between the two. This relationship of ASAT and BMD weapons systems could influence decisions to deploy either one, and may also complicate negotiations to ban or limit weapons for either purpose. The wide variety of ASAT issues are treated by Paul Stares, Kurt Gottfried and Ned Lebow, and Ashton B. Carter.

The second half of *Weapons in Space* begins with an evaluation of how U.S. and Soviet BMD and ASAT efforts could effect the 1972 ABM treaty and other international legal agreements. Particular attention is paid to the SDI program and its implications for the ABM treaty in the article by Abram Chayes, Antonia Handler Chayes, and Eliot Spitzer.

This is followed by analyses of the military utility and political implications of different levels of BMD deployments. An important point in the debate over strategic defenses is that the Soviets can take a number of military countermeasures that will greatly complicate the development of a fully effective defense: it can deploy additional numbers of ballistic missiles, shorten their launch time, and equip their missile systems with various types of penetration aids, including decoys and chaff. All these possibilities have been studied extensively,

and appear both feasible and relatively inexpensive. In contrast, there are many uncertainties regarding the technical feasibility, cost, and survivability of the BMD concepts being studied by the SDI. It is difficult, therefore, to escape the conclusion that the stated goal of obtaining a defense so complete as to make nuclear weapons "impotent and obsolete" is almost surely unobtainable. This is doubly so as effective defenses would also have to be deployed to protect against manned bombers, cruise missiles, and other delivery systems.

It is at least partly in recognition of this that a number of suggestions have been proposed for U.S. deployment of limited defenses that would protect missile silos and other important hardened sites in the U.S.. It is possible that deployment of defenses for some of these partial objectives would be cost-effective. However, their purpose would clearly be to bolster deterrence by retaliation, not to replace it. Discussion of these topics can be found in the articles by Maj. Gen. John Toomay, and George Rathjens and Jack Ruina.

So dramatic a change as moving from deterrence by threat of retaliation to a defense so complete as to make nuclear weapons "impotent and obsolete" is certain to have large political implications. The reactions of the Soviet Union are particularly important, as David Holloway points out in his article, as they will affect not only the feasibility and costs of strategic defenses, but also the likelihood of agreements on mutual arms reductions, and perhaps even the probability of nuclear war.

Reactions of America's allies to the SDI program are covered in the essays by Christoph Bertram, John Wilkinson, T.B. Millar, and Marie-France Garaud. While considerable Allied apprehension about the implications of the new U.S. defense effort clearly exists, there are also significant voices of support for the SDI. It is probably too soon to expect any Allied consensus about the implications of U.S. deployment of strategic defenses. President Reagan's recognition in his 1983 speech of the importance of the NATO alliance, and his pledge to "continue to honor our commitments," was reassuring, but it will be some years before it will be clear how this will be reflected in new and continuing alliance policies.

The concluding article of *Weapons in Space* examines the pros and cons of the debate over the SDI, and considers some of the policy alternatives that the U.S. might consider. A theme that underlies many

of these alternatives is the desirability, perhaps even the necessity, of exploring with the Soviet Union further measures for avoiding war, and the possibility of devising mutually useful ways to employ defense to enhance each nation's security.

GLOSSARY OF ACRONYMS

ABM	anti-ballistic missile
ACDA	Arms Control and Disarmament Agency
ALCM	air-launched cruise missile
AOA	airborne optical adjunct
ASAT	anti-satellite
ASW	anti-submarine warfare
ATBM	anti-tactical ballistic missile
ATP	Acquisition Tracking and Pointing [system]
AWACS	airborne warning and control system
BAMBI	ballistic missile boost intercept [system]
BMD	ballistic missile defense
BPI	boost-phase intercept
BSTS	Boost Surveillance and Tracking System
C ³ I	command, control, communications, and intelligence
DARPA	Defense Advanced Research Projects Agency
DEW	directed energy weapon
DOD	Department of Defense
DOE	Department of Energy
DSAT	defensive satellite
DTST	Defensive Technologies Study Team [Fletcher panel]
ELINT	electronic intelligence
EMP	electromagnetic pulse
FOBS	fractional orbital bombardment system
FOFA	follow-on-force attack
GLCM	ground-launched cruise missile
GEO	geosynchronous orbit
GPS	Global Positioning System [Navstar]
HADS	high-altitude defense system
HF	hydrogen fluoride
HKV	homing kill vehicle
HOE	Homing Overlay Experiment
HSD	hard site defense
ICBM	intercontinental ballistic missile

I 6 *Glossary (cont.)*

INF	intermediate-range nuclear forces
IR	infrared
LEO	low earth orbit
MAD	mutual assured destruction
MaRV	maneuvering reentry vehicle
MIRV	multiple independently targetable reentry vehicle
MSR	missile site radar
NCA	National Command Authority
NTM	national technical means [of verification]
PAR	perimeter acquisition radar
R&D	research and development
RDT&E	research, development, testing, and engineering
RORSAT	radar ocean reconnaissance satellite
RV	reentry vehicle
SALT	Strategic Arms Limitation Talks
SAM	surface-to-air missile
SATKA	surveillance, acquisition, tracking, kill assessment
SCC	Standing Consultative Commission
SDI	Strategic Defense Initiative
SDS	satellite data system
SLBM	submarine-launched ballistic missile
SLCM	sea-launched cruise missile
SSTS	Space Surveillance and Tracking System
START	Strategic Arms Reduction Talks
TNF	tactical nuclear forces
UV	ultraviolet

Nuclear Deterrence and the Military Uses of Space

ON MARCH 23, 1983 PRESIDENT REAGAN made a speech that was almost as unexpected as it was portentous. In it, he called on American science to create a total defense against ballistic missiles, a defense of such qualitative difference that it could support a radical change in our nuclear strategy. Nuclear strategy would no longer be based on offense, but rather on defense; no longer on assured destruction, but on assured survival; or, as some have put it, no longer on death, but on life.

The official name of the program is the Strategic Defense Initiative (SDI), but because the technical ideas underlying it involve deploying defensive weapons in space, the program has come to be referred to—even by most of its supporters—as “Star Wars.”

Although the *strategy* involved in the SDI represents a radical departure from past thinking, the *technology* that underlies it is the direct and logical result of many decades of research and development. Indeed, proposals for using satellites to supplement earth-based military capabilities were first put forth seriously in the mid-1940s. Ten years later, both the United States and the Soviet Union initiated programs designed to implement certain of these ideas. For the next quarter of a century, the development and deployment of these military space assets, as they came to be called, proceeded in a roughly balanced and relatively non-threatening manner. Recent developments—including anti-satellite weapons, the direct use of space assets in warfare, as well as the president’s Strategic Defense

Initiative—are bringing about a new, more costly, and more dangerous phase in this ongoing process.

THE EVOLVING MILITARY USES OF SPACE

As early as 1946, a group of scientists and engineers at the RAND Corporation published a report entitled “Preliminary Design of an Experimental World-Circling Spaceship.” The report was remarkable for its accuracy and prescience. Most of it is devoted to the question of how to build adequate launching systems, and while its estimates in this regard are not perfect, they are very good. More important, the report also devoted some attention to the possible military applications of satellites:

... The military importance of establishing vehicles in satellite orbits arises largely from the circumstances that defenses against airborne attack are rapidly improving. ... Under these circumstances, a considerable premium is put on high missile velocity, to increase the difficulty of interception.

This being so, we can assume that an air offensive of the future will be carried out largely or altogether by high-speed pilotless missiles ... [accordingly] precise observations of the position of the missile can be made from the satellite, and a final control impulse applied to bring the missile down on its intended target. This scheme, while it involves considerable complexity in instrumentation, seems entirely feasible.

Alternatively, the satellite itself can be considered as the missile. After observation of its trajectory, a control impulse can be applied in such a direction, and at such a time that the satellite is brought down on its target.¹

We have here the germ of two important ideas that were realized only decades later. The first finds its modern expression in the current plan to use navigation satellites of the global positioning system (GPS) to provide prompt location and steering information to a variety of weapons systems, including aircraft and missiles, thus increasing their accuracy and lethality. The second is the notion of an orbiting weapons platform, an idea implemented by the Soviets in their fractional orbital bombardment system (FOBS) in the early 1960s.

Other proposed military uses for satellites advanced in the 1946 report included locating targets, observing weather conditions over

enemy territory, and using satellites to relay military communications. The report specified that satellites in geosynchronous orbits—36,000 kilometers above the earth—would be best for this last purpose.

Since no rockets suitable for launching a satellite into orbit existed at that time, it was soon concluded that the potential benefits of satellites would not by themselves justify the very large costs of the development and construction of the necessary rockets. For the next several years, then, work on satellites proceeded on a research basis only. As a result of a series of unexpected events, however—including, especially, the first Soviet A-bomb test, the Korean War, and the discovery of the existence of a substantial Soviet program dedicated to the development of long-range rockets—the U.S. in 1954 decided to establish several parallel programs aimed at developing huge rockets (Atlas, Titan, Thor, and Jupiter) specifically designed to power large and very long-range ballistic missiles. These rockets, of course, proved to be just right for the launching of artificial satellites, and as a result the idea of building such devices took on new meaning. By this time, satellite designers, still concentrated primarily at RAND, had begun to focus on those goals—overhead reconnaissance and early warning—that they felt were most promising for near-term practical use. In short order, a RAND study entitled “Project Feedback” was published on March 1, 1954, delineating these possibilities, followed a year later by a U.S. Air Force contract calling for the development of reconnaissance satellites.

All of these developments were, of course, proceeding on a highly classified basis. At about the same time, but in the public sphere, plans were being elaborated to declare July 1957–58 an “International Geophysical Year.” One of the highlights of the year was to be the launching of artificial satellites that would perform scientific observations of our planet. In 1954 and 1955, work began on two additional satellites: a much smaller scientific satellite called “Project Orbiter,” and the Navy’s “Project Vanguard” (an alternative to “Orbiter”). However, before either of these programs could place a satellite in orbit, the Soviets, to the great shock and surprise of the general public and the Congress, launched the first Sputnik on October 4, 1957.

The launch of Sputnik prompted the U.S. government to undertake a thorough, and often frantic, review of the state of “high-

technology” in America. Out of this came a total revamping and expansion of the then much smaller, but very prominent, civilian space program and the creation of a new agency, NASA, to oversee it. The still very secret military satellite program, on the other hand, experienced only minor changes in either its substance or organization. Like many other “high-tech” programs of the time, however, its priority and funding were eventually substantially increased.

This brief review of the first steps towards the military use of space exposes a fact that is commonly missed or glossed over in the folk-historic views of the origins and nature of our space programs: our space programs, *from the beginning*, have been primarily of a military, not a civilian or scientific nature. Public attention may have focused on Mercury, Gemini, and Apollo and the corresponding Soviet projects, but the fact remains that both the U.S. and Soviet space programs overall have always been driven more by military considerations and requirements than civilian and scientific ones.

Moreover, the military space program has always included a component dedicated to warfighting, as well as components devoted to general intelligence, administration, and logistical support. Our strategic missiles, for example, are currently primed to attack some 10,000 military and industrial targets, mostly in the Soviet Union. For all practical purposes, every one of these targets was discovered and located by reconnaissance satellites and was given precise coordinates by means of data produced by geodetic satellites. Our missile submarines derive their initial coordinates from data provided by navigational satellites. In the future, the use of these global positioning system (GPS) satellites will markedly improve the effectiveness of aircraft and missiles by correcting their trajectories while in flight. Mapping satellites are currently providing the input data for the super-accurate “tercom” (terrain comparison) system that will steer our cruise missiles. And we are already in the early stages of supplying data gleaned by satellites directly to battlefield commanders.

AMBIGUITY OF MILITARY SPACE MISSIONS

Setting aside for the moment consideration of ASATs and the SDI, are the various elements of today’s military space program stabilizing or

destabilizing? Are they benign or aggressive? Are they intended to reinforce deterrence, or is their primary purpose to improve our fighting capability should deterrence fail? The answers to these questions are by no means simple or straightforward.

Let us first consider overhead reconnaissance in the broadest sense. Reconnaissance is used for several major purposes, each of which affects the stability of the relationship between the superpowers. One purpose is *target discovery and location*—the “spotting” function of the 1946 RAND report. Another is *general intelligence* to evaluate the state of preparedness of an enemy. A third is *verification of arms-control agreements*. This last purpose receives most of the attention in those political circles primarily interested in arms control, detente, and diplomatic approaches to solving the world’s problems. But it is the first two purposes that provide the main rationale for spending billions of dollars annually to operate the existing system and to develop new ones. General intelligence-gathering and the verification of treaty compliance are, by and large, stabilizing. Target “spotting” is not. On the one hand, the discovery by satellites in 1961 that there was in fact no “missile gap” between the U.S. and the Soviet Union prevented us from over-reacting to Sputnik even more than we did. In this case, satellite intelligence contributed to stability. On the other hand, these same satellites are also capable of providing data that is sufficiently complete and accurate to make a successful preemptive first strike against land-based military forces seem possible.

Early-warning satellites are similarly ambiguous in their function. They are most important for their ability to give reliable warning of a missile attack twice as quickly as conventional earth-based radars, thus making it more difficult for the enemy to achieve a successful first strike. For this reason, early-warning satellites are said to be stabilizing. At the same time, these same characteristics are important to the launching of a retaliatory strike before absorbing a Soviet attack (launch-on-warning), a tactic advanced by some strategists as the best and cheapest answer to a surprise first strike on our land-based force. By making early warning more accurate, these satellites make launch-on-warning more thinkable.

The data produced by earth-mapping satellites gives modern cruise missiles their exceptional accuracy. Air-launched cruise missiles have as their primary purpose extending the life of the bomber leg of the strategic triad; they are therefore commonly said to contribute to

strategic stability because they reinforce deterrence in a fundamental way. Other types of cruise missiles, such as the ground-launched cruise missiles deployed in Europe, add very little to deterrence itself; they are primarily warfighting devices designed to destroy specific military targets in the event deterrence fails.

Similarly, the GPS, the Soviet radar ocean reconnaissance satellite (RORSAT), and other systems designed to supply critical information rapidly to tactical commanders, are clearly much more sharply oriented towards warfare than towards deterrence. Indeed, these systems belong to a special class of space weaponry that one American official has described as the “most important class of weapons in space,” yet is “almost totally neglected by the arms-control community.”²

Space, then, long militarized and weaponized, is becoming steadily more so. Up to now, however, these developments have taken place in a roughly balanced fashion, in which the actions of one superpower have not generally been construed by the other as immediately menacing or even particularly hostile. The reason for this is not that satellites have made no direct contribution to warfighting, but simply that they have so far done so only by a slow accumulation of data during peacetime. This situation is obviously about to change: new systems—GPS, RORSAT, and the direct use of space-based assets by tactical commanders—will soon be supplying essential data to warfighting systems in real time. Such a move will inevitably be seen as hostile and dangerous by both sides; a clear example of this is the U.S. Navy’s strong reaction to the Soviet RORSAT, whose principal purpose is to locate and target U.S. surface ships.

In what ways, then, would the deployment of a serious anti-satellite (ASAT) capability fit into this existing situation?

ASATS AND MILITARY SATELLITES

The pressure to acquire an anti-satellite capability is a natural response to the superpowers’ increased use of space-based assets for military purposes. Indeed, the very first anti-satellite system was deployed by the United States during the Kennedy administration as a direct and immediate response to two seemingly ominous events in the Soviet Union. One of these was the development of an orbital bombardment system, that is, a system in which bombs would be

deployed on satellites in low orbits and either exploded in space or brought down and detonated at specific points on the ground. The other was the explosion of an extraordinarily large nuclear device in 1961 at Novaya Zemlya in central Asia. While its estimated size was “only” fifty-eight megatons, American scientists believed the Soviets could have easily increased the yield to one hundred megatons or more. Many analysts concluded that bombs of this type could, if exploded at an altitude of one hundred miles or so, set fires on the ground over an area of perhaps a hundred thousand square miles—the area of a typical midwestern American state.

As a natural response to the threat posed by the combination of these two developments, Secretary of Defense McNamara ordered the deployment on Johnston Island of an ASAT system that used a Thor rocket to deliver a nuclear warhead to an altitude sufficient for intercepting bombs in orbit. While the Soviets did in fact eventually deploy a so-called fractional orbital bombardment system (FOBS), and although both the Soviet FOBS and the U.S. anti-satellite system remained deployed for more than a decade, each was eventually decommissioned.

Despite this instance of provocation and response, U.S. authorities during this period declined to authorize the development and deployment of a general purpose anti-satellite system. The rationale was simple: the U.S. relied heavily on satellites for intelligence and support purposes, and it was in our direct interest to maintain the idea of space as a special sanctuary for such systems. If we wanted no Soviet ASAT, we were willing to pay the necessary price: no American ASAT.

The Soviets, however, did not practice similar restraint. As is discussed more fully elsewhere in this volume, they initiated testing of a general-purpose ASAT in 1968.³ After almost a decade of further restraint on our part, the Carter administration in 1977 finally responded to this Soviet ASAT project with a three-pronged approach. The first was the initiation of an ASAT development program of our own. The second was an increased effort to find ways of defending satellites against attack, the so-called DSAT program. Last was the initiation of negotiations with the Soviets designed to eliminate ASATs altogether, if possible, and hence to render the first two responses unnecessary. The Soviet reply was carefully ambiguous, indicating a preference for a “rules of the road” approach (i.e., regulating satellite use) over elimination of ASATs. Indeed, the Soviets

made it clear that they regarded ASATs as a natural response to threats from space, mentioning in this context “third countries” (i.e., China) and “threats against our sovereignty from space.” As it now stands, development of a general-purpose ASAT is going forward on both sides, despite the resumption in March 1985 of U.S.-Soviet negotiations on a broad range of weapons.

The main argument of those who favor ASAT arms control centers on the special uncertainties and dangers that the introduction of general-purpose ASATs will give rise to. So far, warfare, at least in the direct sense, has not extended to space; indeed, we have treaties now in force that were specifically designed to maintain outer space as a zone of peace. The introduction of ASATs, its critics contend, would destroy all that. Satellites whose purposes are largely benign and stabilizing—that is, those we depend on for intelligence, warning, communications, and the like—would be placed in peril and subject to destruction at any time. These critics foresee not only needlessly heightened fears and tensions, but increasing expenditures of money that could otherwise go to more useful military programs or neglected civil needs.

ASAT supporters argue that space will soon harbor even more satellites that contribute directly to an enemy’s warfighting capability, and that it makes no sense, at this late date, to confer on space special sanctuary status. American officials cite the existence of Soviet ocean reconnaissance satellites (RORSAT) and contend that other systems, presumably parallel to those that we are developing, are in prospect.⁴ They point to the difficulties of verifying any ban on ASAT deployment, and argue that new non-nuclear ABM systems (such as the one tested by the U.S. Army in 1984 at Kwajalein Atoll), to say nothing of powerful ground-based lasers and the like, make a treaty prohibiting ASATs too late and impractical.

Given these diametrically opposed positions, how is the American body politic likely to react? One basic fact to consider is that only one-third of the Senate is necessary to block any treaty, and no arms-control treaty that is openly opposed by the armed forces can make it over this hurdle. Although our military leadership is currently split on this issue, a growing majority appears to belong to the camp that regards ASATs as a natural response to a coming threat. Given that the most influential members of the office of the secretary of defense

have similar sentiments, it is unlikely that a treaty totally banning ASATs will be negotiated in the near future.

On the other hand, a treaty establishing clear-cut “rules of the road” could probably be negotiated, even in the present circumstances. The world has had such rules governing behavior at sea for centuries. The oceans are full of fighting machines, yet these co-exist easily with civilian ships during peacetime. A similar arrangement could surely be worked out for space, one that would give all parties the same kind of assurance of safe passage for military as well as civilian satellites during peacetime that is now the case for all nations’ warships now at sea. Such a policy could go a long way in guaranteeing the survival of intelligence and warning systems, as well as other systems that add to both international stability and military readiness in peacetime (in the event of a major war, of course, all space assets would be in grave danger). As with all high-technology weapons systems, especially nuclear systems, it is those components that play a major role in deterring war that should command primary attention, not those that would be important in combat, should deterrence fail. Of course, a total ban on ASATs would be the best way to reassure the continuing role of our space assets in deterring war, but a “rules of the road” agreement, if carefully crafted, could accomplish this almost as well, and from a practical political perspective seems much more feasible.

SPACE AND STRATEGIC DEFENSE

The president’s new Strategic Defense Initiative was introduced into a world in which the militarization of space by the United States and the Soviet Union was already solidly underway, and in which it was widely recognized that this process ought to be limited or contained before it escalated beyond our control. Indeed, the technological side of the SDI is based, to a large extent, on concepts already deployed or currently under development in military space programs. Approximately 90 percent of the 1985 SDI budget is devoted to continuing the development of devices and the exploration of ideas that were already programmed *before* the SDI was introduced in March 1983.

For all practical purposes, the technological side of the SDI consists of those ideas, devices, and systems discussed in the report of the Fletcher panel, one of three committees set up by President Reagan to

investigate strategic defense.⁵ This report called for the creation of a multilayered defense system made up of a variety of components designed to detect, target, and destroy attacking ballistic missiles and their nuclear warheads all along their trajectories from their initial launch to their final targets. As noted above, most of the systems involved were based on concepts either already employed in our military space program or in various stages of development for possible future space applications. Many others were taken from terminal ballistic missile R&D programs established over a quarter of a century ago. And some came from unrelated programs, particularly from the research laboratories of our defense establishment. Among these are the so-called "Third Generation Weapons," including laser and particle beams and kinetic energy weapons that are considered especially useful in a defensive mode against Soviet missiles in boost phase, immediately after they have been launched.

There is, of course, much debate over whether the SDI will result in a total defensive system possessing the characteristics and qualities necessary to bring about the strategic revolution the president called for. We can here summarize this debate by examining two quotations from expert studies of the issue. On the one side, the Fletcher panel noted that: "By taking an optimistic view of newly emerging technologies, we concluded that a robust BMD system can be made to work eventually. The ultimate effectiveness, complexity, and degree of technical risk in this system will depend not only on the technology itself, but also on the extent to which the Soviet Union either agrees to mutual defense arrangements and offense limitations, or embarks on new strategic directions in response to our initiative."⁶

On the other side, in a report written by Drell, Farley, and Holloway, we find the statement: "We do not now know how to build a strategic defense of our Society that can render nuclear weapons impotent and obsolete as called for by President Reagan. Nor can one foresee the ability to achieve the President's goal against an unconstrained, responsive threat."⁷ Many other studies by knowledgeable experts have reached very similar conclusions.⁸

Note that experts on both sides agree that the present technology cannot produce a system adequate to the president's goals; the disagreement is over whether the technology that will become available in the next ten or twenty years will be adequate to provide a truly useful level of defense, and whether the best way to generate

such technology is to proceed along the lines now being proposed in the Department of Defense. The argument is actually over the future course of technology: to what degree we can extrapolate from existing know-how to estimate our capabilities in the distant future.

SPACE WEAPONS AND NUCLEAR DETERRENCE

During a press interview conducted soon after his “Star Wars” speech, President Reagan was asked about his new initiative. At one point he replied:

To look down on an endless future with both of us sitting here with these horrible missiles aimed at each other and the only thing preventing a holocaust is just so long as no one pulls the trigger . . . this is unthinkable.⁹

In giving this answer, the president, perhaps unwittingly, joined a host of others who believe that peace through a balance of terror is untenable in the long run, that deterrence through the threat of mutual assured destruction (MAD) cannot be the basis for an enduring peace, that the threat to kill hundreds of millions of civilians as punishment for some unacceptable political act by their government is immoral in the deepest sense of the word. These ideas are not new; all previous U.S. presidents have held similar ideas, and as far as we can tell, so have all Soviet leaders, at least since Stalin. The problem is—and has been for forty years—that no viable alternative presents itself. Supporters of nuclear deterrence have often pointed to the fact that, whatever the long-term prospects may be, deterrence has so far “worked”; that peace in Europe has been preserved for more than forty years, a time during which any number of crises might otherwise have precipitated a major war.

The introduction of nuclear explosives and other high-technology weapons only a few decades ago resulted in a radical change in the vulnerability of both the United States and the Soviet Union. Before that, the oceans that had from our origins isolated us from the rest of the world still protected us from both invasion and attack. And in 1941, when the Nazi war machine attacked the Soviet Union, the great size of that country enabled it to absorb the full weight of attack long enough to rally, muster outside help, and turn the tide of the invasion. Today, each of the superpowers could, if it chose to, literally annihilate the other in less than an hour, and the only

recourse either nation has to forestall such a horror is to threaten to wreak revenge in kind. That is the stark meaning of Reagan's obviously heartfelt remark that the only thing preventing a nuclear holocaust is the fact that no one is pulling the trigger. Nor is this stalemate a static situation; things are in fact becoming steadily worse. The thoroughness of the potential destruction is increasing, the chance of survival for individuals and for civilization itself is decreasing. The combination of technical improvements in accuracy and multiple warheads (MIRVs) is making the possibility of a first strike seem, at least to some, more thinkable. To guard against this, some strategists advocate a policy of launch-on-warning, though such a strategy carries with it the possibility of accidental war. And last but not least, the ability to wreak this sort of total devastation is slowly but steadily spreading to more countries.

In sum, for forty years now our military power, as measured by our ability to wreak death and destruction on an enemy in an even shorter time, has been steadily increasing. At the same time, our national security, as measured by the combination of the ability of others to wreak death and destruction on us and our inability to do anything about it, has been steadily decreasing. This has been, and remains, our mutual and fundamental security dilemma.

Spiritual leaders such as the Pope and the American and French Catholic bishops have perceived the issue not very differently from our political leaders. While they have all condemned the use of the threat of nuclear annihilation as the principal means of maintaining peace, they have in various ways also said that this can be tolerated so long as we have no alternative way of avoiding large-scale war. More important, they have added that the current situation is tolerable only so long as we are actively and seriously seeking alternatives. Not everyone may agree with the way these spiritual leaders have stated their case, but nearly everyone believes that we should indeed be seriously seeking alternative ways of maintaining stability and assuring peace.

Our lives, the lives of our progeny, and the continuation of our civilization do depend on "nobody pulling the trigger." That, truly, "is unthinkable," and necessarily evokes extreme proposals for a solution. Some people suggest panaceas: general and complete disarmament, unilateral nuclear disarmament, the abolition of sovereignty, the creation of a super-state, and, not so long ago, preemptive

wars (America against Russia, Russia against China). Others have solved the problem in their own minds by wishing it away; some in this group suggest that the Russians aren't nearly so bad as our leaders say, and if we would only stop provoking them all would be well. Still others suggest that if our leaders would only "stand tall in the saddle" our enemies would be cowed into decent behavior.

Where does the SDI stand in this regard? Is it a technological panacea, mere wishful thinking, or is it a grand idea whose time has come?

From the beginning of the nuclear age until the Reagan administration, all American presidents have placed great emphasis on searching for and exploiting political means for maintaining peace and stability and have played down the possibility of an active defense against a nuclear attack. In addition to maintaining an adequate level of nuclear deterrence, they forged and strengthened alliances, they pursued detente and peaceful coexistence by a variety of diplomatic means, and they sought to negotiate agreements that would first limit and eventually reverse the nuclear arms race among the nuclear powers and prevent its spread to other nations. This has not been a partisan matter: every president from Truman to Carter—four Democrats and three Republicans—placed the same trust in political measures, including arms negotiations, as the favored alternative to the naked threat of nuclear revenge as the means for averting large-scale war. In addition, all of the postwar presidents also supported research and development on a variety of active defense schemes. In the 1940s and early 1950s, primary attention was focused on the construction of air defenses intended to keep long-range bombers away from our shores. In the 1960s, the primary focus was on the development of anti-ballistic missile systems. While the prospects for such systems have waxed and waned in accordance with the technological facts as well as the temper of the times, at no point in the thirty years prior to President Reagan did a president place greater emphasis on developing technological means of defense against nuclear attack than on promoting political means for maintaining international stability and world peace.

It is this balance between the search for technical solutions and the search for political solutions that President Reagan seems intent on changing. We now have the president's challenge to scientists to build a defense so effective that it might eventually "make nuclear weapons

impotent and obsolete,” a challenge accompanied by an extraordinary national program administered by a specially created new organization. We also have a long list of statements by the president and some of his closest advisers and political associates concerning the perfidy of the Soviet leaders, and the consequent difficulty of making any useful agreements about important matters with them. While this has not prevented the two countries from resuming arms-control negotiations in March 1985, the complexity of combining negotiations on strategic offensive *and* defensive systems makes the outcome of these talks very problematic.

Is there reason to believe this new approach would be better than the one favored by other presidents? Is there reason to hope that we can, at last, find security through technology? The unhappy fact is that, thus far, whenever we (or others) have sought to solve our national security dilemma by technical means, we have in the end only made matters worse. Back in the 1940s and 1950s, the answer to active air defenses was the introduction of ballistic missiles. Ballistic missiles overflowed the air defense, making the attack more certain and much quicker. In response to ABM defenses, efforts in the early 1960s to put multiple warheads on missiles (MIRV) were accelerated. This increase in warheads could saturate and swamp any conceivable defense, at the same time making it possible to increase greatly the number of individual targets that could be attacked. MIRVs, however, make the world more dangerous because, when combined with increased accuracy, they make a first strike seem more promising, thus undermining stability in certain crisis conditions.

* * *

It is easy to understand why we look to high technology for solutions to our military problems. The United States, after all, is the world leader in this area; technology truly is one of our strongest suits. Those who support various extreme “high-tech” ideas, such as the SDI, can and do point to any of a number of remarkable and dramatic past successes. Radar did tip the balance in the Battle of Britain, and nuclear bombs did end World War II earlier than would otherwise have been the case. In 1961, a president issued an order to go to the moon within the decade and we did precisely that. On an everyday level, our homes and lives are filled with “technological

miracles," including televisions that pick up signals relayed by satellites from around the world and home computers as powerful as the largest of their institutional ancestors only a generation ago. The computer revolution, after thirty years of surpassing most short-term predictions, seems destined to offer equally rapid rates of change in the years ahead.

Against this background, the Fletcher panel's optimistic extrapolations of current capabilities are not *prima facie* unreasonable. On the other hand, we must note that most of these frequently cited technological triumphs involved a struggle of man against nature; the SDI, while it does require some new inventions, also involves a struggle of man against man—of measure against countermeasure—and that is quite a different matter.

We are truly on the horns of a dilemma. Is the SDI, as some think, an instance of exceedingly expensive technological exuberance sold privately to an uninformed leadership by a tiny in-group of especially privileged advisors? If it is, then it is a perfect example of what President Eisenhower had in mind when he warned that "in holding scientific research and discovery in respect, as we should, we must also be alert to the equal and opposite danger that public policy could itself become the captive of a scientific technological elite."

Or is the SDI, as others maintain, a good idea whose time has come? Is it a possible means for replacing assured destruction by assured survival, even, perhaps, for eventually making nuclear weapons obsolete? The issues involved in the debate over strategic defenses are many and complex, and the debate itself will surely go on for many years. What will be vitally important during this debate is that the American public realize that the SDI is not proceeding in a vacuum, but is enmeshed in a web of issues concerning defenses against all types of nuclear weapons, as well as current and projected military uses of space, anti-satellite weapons, offensive nuclear forces, and strategic stability between the superpowers.

ENDNOTES

¹*Preliminary Design of an Experimental World-Circling Spaceship*, (Santa Monica: RAND Corporation, 1946); see especially the section on the possible military applications of satellites by Louis Ridenour, "Significance of a Satellite Vehicle."

²Dr. Robert Cooper (director of the Defense Department Advanced Research Projects Agency), *The San Diego Union*, June 17, 1984, page C4.

³See the contribution to this volume by Paul Stares, "U.S. and Soviet Military Space Programs: A Comparative Assessment," on p. 127.

⁴Speaking about the ocean reconnaissance systems specifically, Dr. Cooper noted that the Soviets have completed a number of experiments designed eventually to provide "over the horizon targeting" information directly from satellites to missiles launched from submarines and aircraft. Given the ability of both aircraft and missiles to achieve much greater accuracy by using satellite data for in-flight navigation, the military need for ASAT weapons to destroy such satellites will become stronger. See *The San Diego Union*, June 17, 1984, page C4.

⁵For the unclassified summary of the Fletcher panel report, see "The Strategic Defense Initiative: Defensive Technologies Study" (Washington, D.C.: Department of Defense, March 1984).

⁶James C. Fletcher, "The Strategic Defense Initiative," testimony before the Subcommittee on Research and Development, Committee on Armed Services, U.S. House of Representatives, March 1, 1984.

⁷Sidney D. Drell, Philip J. Farley, and David Holloway, *The Reagan Strategic Defense Initiative: A Technical, Political and Arms Control Assessment* (Stanford: Stanford University, 1984).

⁸See especially Ashton B. Carter, *Directed Energy Missile Defense in Space*, Office of Technology Assessment Background Paper (Washington, D.C.: U.S. Congress, 1984) and John Tirman, ed., *The Fallacy of Star Wars* (New York: Vintage Books, 1984).

⁹*The New York Times*, March 30, 1983, p. A14.

Ballistic Missile Defense: Concepts and History

IN THE HISTORY OF WARFARE there has been a continuing contest for supremacy between offensive and defensive weapons. Advances in technology or the military art have at various times made either the offense or the defense temporarily dominant, but sooner or later the pendulum has swung back the other way. It has thus become an axiom of warfare that for every weapon or tactic a counterweapon or countertactic can be found.

Had it not been for the invention of nuclear weapons, this dialectic of offense and defense might have been expected to continue indefinitely. The destructive power of nuclear weapons is so enormous, however, and their means of delivery so swift and effective, that much doctrine in the nuclear age has postulated a virtually permanent advantage for the offense. The advent of the ballistic missile as the principal means of delivery has reinforced this. A prevailing belief thus emerged in the mid-1960s that nationwide deployment of an anti-ballistic missile (ABM) system to protect the United States against heavy attack by Soviet ICBMs was not feasible.

Instead, a strategic policy evolved that came to be known as mutual assured destruction (MAD). It was based on the maintenance of strategic nuclear forces (ICBMs, SLBMs, and bombers) that could survive a first strike in sufficient numbers to pose an unacceptable threat to the adversary's population and industrial centers. In agreeing to the ABM treaty of 1972, the Soviet Union tacitly accepted the concept of offensive dominance, if not the entire concept of MAD.

Neither side has so far been entirely happy with the idea that its survival is dependent on retaliatory forces, that there is no such thing as an adequate defense. This concept sits especially hard with the Soviet Union, which is surrounded by potentially hostile neighbors and has suffered repeated devastating attacks throughout its history. It is not surprising, therefore, that a strong bias towards defense permeates Soviet military and political doctrine.

In the United States as well there has been growing discontent with MAD. One response has been the new emphasis placed on defensive technologies by the Reagan administration's Strategic Defense Initiative (SDI).

In examining the offense-defense relationship in the era of strategic nuclear weapons, this chapter seeks to illuminate the baseline from which the SDI must start.

U.S. BALLISTIC MISSILE DEFENSE PROGRAMS

At its inception, ballistic missile defense was regarded by many as a natural extension of the concepts concerning guided missile systems for air defense. The equipment would have to be more powerful and complex, but the basic architecture of defensive systems, the underlying military doctrine, and the degrees of effectiveness were assumed to be parallel.

At first, each military service sought to extend its own mission to include the BMD challenge. Different modes of BMD were explored by the Air Force, which used interceptor aircraft for area defense of the United States, and the Army, which had responsibility for protecting military and civilian targets with surface-to-air missiles (SAMs). It was quickly realized, however, that the distinction between area and terminal defense was less relevant in an age of nuclear-armed ballistic missiles, and the new BMD programs were assigned to the Army alone.

By early 1957, the Army was working on Nike Zeus, a system of radars and interceptor missiles for high-altitude interception of incoming ballistic missiles. By mid-1962, prototypes of the radars and missiles were ready for a test against a live missile, and in December 1962 the system successfully intercepted an Atlas D missile.

During this period, however, attention was also being given to the problems of countermeasures, i.e., those means an adversary could take to foil an ABM system. Indeed, the U.S. military was studying various types of countermeasures, including decoys (dummy warheads) and other “penetration aids,” both to see what the Soviet Union might be capable of doing to breach our defenses and to ensure that U.S. ICBMs would be able to penetrate a possible Soviet ABM system. As a result of the R&D efforts given to penetration aids, the steadily increasing numbers of ballistic missiles in the Soviet inventory, and the rapidly evolving radar and computer technology, no persuasive case for deployment of an ABM system based on the Nike Zeus development could be made. There was also growing concern in the political sector over the effects that deployment of an ABM system might have in accelerating the arms race and potentially decreasing strategic stability in a crisis.

Research and development efforts for BMD turned next to seeking ways to counter decoys and other countermeasures. It had already become apparent that decoys could best be dealt with by intercepting the actual warheads at low altitude, since the atmosphere acts as a filter, slowing down or burning up less massive bodies, making it much easier to distinguish between decoys and actual warheads. Thus, a key component of an improved system would have to be a low-altitude interceptor capable of extremely high acceleration so it could be fired late in the reentry trajectory of the incoming warhead. Initial R&D on the needed components was well under way when, in 1963, the Army’s BMD program was redirected toward a new system, Nike-X, that would incorporate just such a low-altitude intercept capability and use better radars.

The new high-acceleration missile, named Sprint, entered development in late 1963 and remained an essential component of subsequent systems. Equally important was the development of an entirely new set of phased-array radars to replace the original Nike Zeus set. The target track, missile track, and discrimination radars were all replaced by a single phased-array radar, the missile site radar (MSR). Phased-array radars, in addition to their ability to perform multiple functions, had the advantage of fixed installations that needed no mechanical scan and could be much more easily protected.

Sentinel and Safeguard

From 1963 to 1967, development work proceeded on Nike-X, and studies were made to evaluate the capability of the system. Among these were studies of terminal defense of Minuteman silos against a heavy Soviet attack and area defense against a light attack by a third country, specifically China. Nonetheless, the case for extensive deployment of the system was not persuasive. In the summer of 1967, though, it became apparent that something (perhaps the White House) had swung support towards deployment of a system designed primarily to protect U.S. cities against a light attack.

The system, which was called Sentinel, would incorporate an improved Nike Zeus missile, the Spartan, for high-altitude interception and the new Sprint missile for low-altitude interception. Both missiles carried nuclear warheads. The missile site radar developed for the Nike-X was to serve essentially the same functions as previously contemplated. A new phased-array radar, called the perimeter acquisition radar (PAR), was to perform long-range surveillance and also track incoming warheads to support Spartan interceptors.

As the Sentinel program proceeded toward deployment, public realization that the proposed sites, including some in urban areas, would have numerous missiles with nuclear warheads, stirred strong opposition. With the arrival of the Nixon administration, construction was suspended in early 1969 pending a presidential decision. On March 19, 1969, President Nixon announced that the Sentinel system deployment would be “substantially modified” and in its new form would be known as Safeguard. The Safeguard system was comprised of the same missile and radar components as Sentinel, but was to be deployed in different numbers and locations. The first priority for the deployment was the protection of U.S. nuclear forces against a Soviet attack; the second priority was the provision of a nationwide defense against a hypothetical Chinese attack—hypothetical, because China did not (and does not) have deployed ICBMs that could reach the United States. A subsidiary role was defense against accidental attack from any source. The Safeguard proposal rekindled political opposition to any ABM deployment and almost failed to receive Congressional approval.

Deployment proceeded on the initial phase, which provided for defense of the hardened Minuteman sites at Grand Forks Air Force Base in North Dakota and at Malmstrom Air Force Base in Montana. The signing of the ABM treaty in 1972, however, radically changed Safeguard deployment plans. The treaty, together with a subsequent protocol, permitted a total of only one hundred interceptors in only one of two types of deployment, for defense of a strategic missile site or for defense of the national capital. The U.S. quickly made the decision to defend only the Minuteman missile site at Grand Forks Air Force Base. This deployment became operational in mid-1975, but in the following year, on Congressional initiative, even this installation was phased out.

SOVIET BMD PROGRAMS

Justification for the pace of U.S. BMD activities has come as much from perceptions of Soviet defense activity as from what at first might seem a more appropriate motivation—the desire to counter Soviet offensive ballistic missile forces. The reasons for this are complex and include strategic policy, foreign policy, technical and economic feasibility, and domestic politics. Presidents Eisenhower, Kennedy, and Johnson showed great disinclination to have the U.S. take the lead in deploying ABM systems. The one disturbing factor was the threat of a massive deployment of an ABM system by the USSR. Indeed, by 1962, senior defense and political officials in the USSR had made public statements implying that effective ABM systems were being developed.

Origins of Soviet BMD

Following World War II, the Soviets, like the U.S., embarked on ambitious programs to deploy surface-to-air missiles, based in part on information and experimental hardware acquired from a defeated Germany. Their first operational anti-aircraft system, the SA-1 (Western designation), began to be deployed around Moscow in the mid-1950s. Like a similar U.S. system, the Nike Ajax, it was effective only against World War II-style bomber raids. This was followed very quickly by several new surface-to-air missile systems capable of interception at much higher altitudes and longer ranges than the SA-1.

Of these, the one that could be interpreted as having at least some ABM capability was the “Griffon” missile system that began to be deployed around Leningrad about 1960. This system, however, was not deployed at other locations. The early version of the more mobile SA-2 air defense system, which was being deployed in the same period, did not appear to most analysts to be a likely candidate for a major ABM role.

About 1963, another new missile called the SA-5 was being widely deployed in the USSR. Unlike the earlier missiles, it was estimated to have a long-range, high-altitude intercept capability. Features of the SA-5 suggested at least some ABM capability, although it clearly also had long-range capability against high-altitude supersonic aircraft of the U.S., such as the XB-70 that was in development at that same time. The XB-70, however, was never produced and deployed. The U.S., in fact, had publicly declared that its bomber penetration tactics would rely on very low-altitude flight so as to evade the coverage of radar and surface-to-air missiles. The SA-5 system appeared to have little low-altitude capability; the SA-2 and SA-3 missile systems, which were then entering the Soviet inventory in increasing numbers, seemed a much more effective response to low-altitude penetration of bombers.

To many U.S. analysts, the massive and expensive deployment of the SA-5 system for defense against high-altitude bombers made no sense. Therefore, it seemed prudent at first to assign at least a dual role to the SA-5 as both a high-altitude bomber defense and an ABM. Gradually, however, as more information on the system became available, the preponderance of expert opinion swung away from crediting the SA-5 system with significant ABM capabilities.

The Moscow ABM System

As perceptions of the SA-5 as an ABM system faded away, growing information on a new system being deployed in a ring around Moscow left no doubt that the Soviets were indeed deploying an ABM system; it is now known in the U.S. as the ABM-1 system. The interceptor missile, the Galosh, was first publicly displayed in 1964. As more information became available, it became obvious that Galosh, which is assumed to be nuclear-armed, was designed for long-range high-altitude interception.

Eventually, the ABM-1 system consisted of complexes at four sites around Moscow. Each site had sixteen launchers and two sets of missile-tracking and guidance radars, for a total of six radars per site. Initial tracking of incoming ICBMs, threat assessment, and target hand-over to missiles for defense was provided by a very large phased-array radar. Later, a second radar of the same type was added at another location.

In addition, the Soviets deployed eleven radars at six locations on the periphery of their territory. It remains unclear whether these radars contribute significantly to ABM performance, other than to give early warning. Like corresponding U.S. radars, these radars have a collateral tracking role for space satellites (a role permitted by the ABM treaty), and there is always some degree of ambiguity about the function of radars of this kind.

The ABM-1 deployment around Moscow is capable of defending a large area of the western Soviet Union. However, being a high-altitude intercept system, it is vulnerable to countermeasures such as chaff and lightweight decoys. Moreover, the frequencies of the system's radars are relatively low and subject to blackout from nuclear blasts, either offensive or defensive. In addition, the large radars are few in number and could be destroyed by a few missiles during a concentrated attack. Finally, since the ABM-1 system itself is limited by the ABM treaty to no more than one hundred launchers, it could be easily exhausted in a concentrated attack.

In an era when there are thousands of ICBM and SLBM warheads on each side, the only plausible rationale for the Moscow system seems to be as a marginal defense against a third country (Britain, France, China), as a precaution against accidental or unauthorized launches of a few missiles, and/or as an initial stage of a possible wider deployment, especially in the event of a breakdown in the ABM treaty.

ROLES FOR BMD

As weapons technology and doctrine have evolved, so too have the roles for BMD. In the early 1950s, the role of defense was to limit damage to the population, industry, and economy as well as government and military installations. This notion also fitted the prevailing concepts of air defense and civil defense, attitudes that were primarily

a legacy of World War II. These concepts were carried over into the nuclear weapons era, at first without any real appreciation of the enormous difference between conventional weapon and nuclear weapon attacks.

Damage Limiting

Population defense is a special case of damage limiting. It makes little sense to protect a population without also providing the resources required for post-attack survival and recovery. And since large fractions of the population and the logistic support for the population are to be found in major metropolitan areas, it is these areas that would have to be given the greatest emphasis.

A definitive Defense Department study on damage limiting, including consideration of air defense, was carried out in 1964. Air Force Brig. Gen. Glenn Kent, then on the staff of the Directorate of Defense Research and Engineering, analyzed data from all Defense Department offices to arrive at a devastatingly negative appraisal of the cost-effectiveness of defense against attacks by nuclear-armed ballistic missiles. For Soviet missiles attacking U.S. targets in numbers ranging from a few hundred to a thousand, the cost-exchange ratio—that is, the cost to the defense of countering each additional offensive warhead—would be intolerably high, varying from three-to-one to ten-to-one. One of the key issues in the current debate on the merits of new types of ABM systems is whether new technologies have made it possible to obtain a reversal of this unfavorable ratio.

Defense of Military Command-and-Control Centers

One of the problems that has been most worrisome for military planners has been the threat of a successful attack on the national command centers and the communication systems connecting them to the strategic forces. Although the national command centers of both the U.S. and USSR are located in the national capitals, each country has developed alternate and mobile command centers and has arranged for devolution of command responsibilities. Nevertheless, there is concern that surprise attacks on the command centers could significantly reduce the effectiveness of a retaliatory attack.

Moreover, attacks on communications systems could involve the detonation of just a few nuclear weapons at high altitude. This would subject command and communication systems on the ground to

electromagnetic pulses (EMP) of tens of thousands of volts per meter, large enough to burn out or damage electronic equipment.

Accordingly, any defensive system cannot rely only on active BMD defenses for individual critical centers, such as Washington, D.C., or the military command center at Cheyenne Mountain in Colorado. Protection against EMP, involving the hardening of electronic equipment and the use of alternate communication channels, as well as alternate and mobile command centers, will be just as essential, with or without active defense.

While it is possible that BMD systems could provide a subjective increase in confidence for defense, and that a parallel increase in uncertainty might help discourage an attacker from making a first strike, it can also be argued that such uncertainty could result in the offense enlarging its ballistic missile and other nuclear forces to assure achievement of its objectives. The issue then reverts to questions of cost-effectiveness and cost-exchange. In any case, arguments for the use of BMD for defense of command centers alone are hardly likely to justify the cost of an ABM system.

Light Defense Against Third Countries and Accidental Launches

While the utility of BMD against massive attacks by a heavily armed attacker is questionable, more persuasive cases have been made for BMD against missile attacks by third countries (i.e., other than the two major powers) and against accidental or unauthorized missile launches. As noted earlier, the need for light defense against a possible Chinese ballistic missile threat led to plans for the deployment of the Sentinel system, while Soviet perceptions of the limited threats from the British, French, and Chinese missile forces have probably played a part in their deployment of ABM-1.

The difficulty with light defense deployments by one of the major nuclear powers is that they might be used as a base for eventual heavier deployments. The thin BMD system might also be converted to achieve other objectives, such as greater protection of ICBMs. This can be accomplished in relatively short order with little hardware change, as exemplified by the metamorphosis of the Sentinel system into the Safeguard system.

Defense of Deterrent Forces

The Safeguard system, the only ABM system actually deployed by the U.S., had as its primary objective the defense of Minuteman ballistic missile silos. This was also a secondary objective of its predecessor, the Sentinel system, which used the same interceptor and radar components. But at the time of the decision to proceed with Sentinel, the Air Force objected to this approach on the grounds that the system's radars were too few and too soft. Moreover, because the system was not designed specifically for silo defense, it was a highly cost-ineffective way to "buy back" a threatened Minuteman silo; it would be cheaper to buy an additional Minuteman if that option were not foreclosed.

However, constructing super-hard silos makes active defense of missiles a much more tractable task. Very low altitude defense is also feasible, and this greatly alleviates the decoy problem, since the atmosphere can be relied on to sort out the decoys. Finally, relatively high rates of leakage can be tolerated, since with adequate silo separation each warhead can destroy only one silo. Thus, even if 20 or 30 percent of the incoming warheads penetrate, there may still be a formidable retaliatory force.

The key to the effectiveness of hardened silo defense is the possibility of low-altitude interception very close to the target silo. This should lead to smaller, lighter, and cheaper defensive missiles, engagement radars, and so forth, but such advantages have yet to be realized. Even less sophisticated systems for point defense of super-hardened silos have been suggested. Richard Garwin, for example, has proposed the "swarmjet" concept, which employs large numbers of short-range rockets to defend each silo. Such close-in defense systems are advantageous from an arms-control standpoint because they cannot be converted to protect large areas.

Using mobile missiles in combination with multiple silos or other protective shelters gives added leverage to systems for defending hardened silos. This concept was originally proposed by the Carter administration for deployment of the MX. An important aspect of this leverage is the fact that only those few silos occupied by missiles need be defended, while the attacker must target all the sites even though most are empty. The possibility of saturating defensive systems is thus greatly reduced.

Tactical Ballistic Missile Defense

ABM systems that can intercept short- and medium-range ballistic missiles, such as those deployed in Europe, are not precluded by the ABM treaty. Almost any high-altitude SAM system, such as the U.S. Nike Hercules or the newer Patriot or Soviet SA-5 could, with relatively small modifications, be used to intercept short- to medium-range tactical ballistic missiles. Several demonstrations of this capability have taken place. The newest missile system to be credited with a tactical ABM capability is the Soviet SA-X-12, which is said to be nearing deployment.

Whether or not such systems will be effective against shorter-range ballistic missiles is another question. The shorter range and time of flight of these missiles, in conjunction with multiple warheads and countermeasures such as lower trajectories and radar jamming, could make the task of tactical defense as difficult as strategic BMD.

COUNTERMEASURES TO ABM SYSTEMS

The effectiveness of an ABM system is not simply a matter of whether the system can intercept and destroy ICBMs and their warheads. In the U.S., at least, a major consideration has been the projected effectiveness of the system in the face of plausible countermeasures. Most defense analysts agree that a countermeasure is plausible if it could be developed within the projected lifetime of the ABM system and could be deployed at a cost no greater than that of the defensive systems being countered.

Yet countermeasures, even if reasonably well-defined, will be viewed differently by attackers and defenders. The attacker may demand great certainty that the countermeasures will succeed (the offense conservative view), while the defender may demand great certainty that the defensive system will remain highly effective in spite of the countermeasures (the defense conservative view).

The gap between offense and defense conservative views of countermeasures leads to many points of contention, not the least of which is the effect of the uncertainty itself. Opponents of ABM argue that the opponent will adopt an offense conservative response and increase the size of his attacking force in an effort to make the

introduction of any ABM capability counterproductive. Proponents, on the other hand, argue that the uncertainty brought about by introducing ABM can be a powerful contribution to deterrence.

Multiple Warheads

The best countermeasure against an ABM system is to increase the number of warheads carried by each missile. Increasing the number of warheads is highly effective against both soft-area targets (cities) and hard targets (missile silos), especially as improvements in accuracy have offset the lower yield of these warheads.

The first multiple warhead missile was the submarine-launched (SLBM) Polaris A-3, which carried three warheads. Later, multiple independently targetable reentry vehicles (MIRVs) were developed, with up to three on the Minuteman ICBM and up to fourteen on the Poseidon SLBM. Although the SALT agreements have placed limits on the number of warheads permitted, some Soviet ICBMs could carry as many as twenty to thirty warheads.

Decoys and Chaff

Relatively lightweight objects can be designed to appear to radar as additional warheads. Unsophisticated decoys (e.g., radar corner reflectors) may weigh only a few pounds, and a hundred or more of these can fit in the space required for a single warhead. As mentioned earlier, however, these lightweight decoys function well only in the early phases of detection and tracking and are not an important countermeasure against terminal ABM systems.

Heavier decoys, weighing perhaps up to 10 percent of a warhead's weight, can be much more effective against radars. With thrust augmentation, they can mask slowdown effects enough to degrade a substantial part of the high-altitude capability of an ABM system. These heavier decoys can also be very effective against mid-course ABM systems using radar or infrared sensors, even those that are relatively sophisticated.

Radar chaff, consisting of very thin wires deployed in long trails surrounding each warhead, is a relatively lightweight, simple countermeasure that is effective during mid-course and early reentry. Chaff is the cheapest and lightest approach, especially when a "bus" is used for MIRV deployment.

Jammers

Jammers that generate radar noise to overwhelm meaningful signals can also be used against ABM radars. A large number of small jammers dispensed over an area covering the paths of incoming missiles can deny detection and tracking or generate false targets down to low altitude. Since jammers need only emit for the short period of attack, electronic components and power supplies can be very small and light.

Maneuvering Warheads

Most of the radar countermeasures described above (except for proliferation of warheads) function only against the high-altitude aspects of an ABM system. Low-altitude interception would not be affected by these countermeasures. One countermeasure that can be effective against low-altitude interception is a warhead that maneuvers during reentry so that prediction of intercept points and targets becomes difficult. Maneuvering warheads are especially effective against preferential defense tactics.

There are drawbacks to this countermeasure. Depending on the degree of maneuvering desired, this countermeasure may increase the weight of the warhead by anywhere from a few percent up to 50 percent. Maintaining hard-target kill accuracy also imposes design constraints on maneuvering and affects weight and cost. However, for ICBMs with large payloads such as the Soviet SS-18s, the tradeoffs may not be too severe, especially as improvements in accuracy permit reduction of warhead yield and size.

Infrared Countermeasures

The problems ABM radars have in seeing through chaff and in discriminating decoys from warheads led to investigation into the use of long-wave infrared sensors for these purposes. As a result, in the late 1960s and the 1970s, some interest developed in countermeasures against such infrared-based systems, and research and limited flight experiments were carried out.

In particular, lightweight balloons made of reflective and insulating surface materials can be designed to simulate warheads. Furthermore, using a technique known as anti-simulation, the warhead itself can be shrouded by an outer shell to make it appear to be a decoy.

Very large numbers of simple balloons can be deployed in combination with more sophisticated decoys to create large volumes of "traffic." Infrared chaff can also be dispersed.

Against these countermeasures, very high-altitude and mid-course ABM systems would have to employ a multitude of sensors to identify warheads on the basis of small or transient differences. Such capabilities go well beyond anything heretofore contemplated in ABM systems. This problem is being investigated by the Strategic Defense Initiative program, but no well-defined, workable, integrated system has yet been publicly described. Many analysts doubt that such a system can be devised.

Finally, infrared sensors can be blinded by nuclear explosions ("red-out") in the same way that radars are blinded ("blackout").

Radar Cross-section Reduction

In ABM systems, radar has been the primary sensor for early detection, target acquisition, and tracking of incoming missiles. Radar cross-section reduction has therefore been an important countermeasure, since it reduces the distance at which radar detection first takes place and decreases the time available for response.

Reduction of radar cross-section can be accomplished by covering the reentry vehicle with a shield that functions through mid-course and early reentry, or by reducing the cross-section of the reentry vehicle itself.

With powerful ABM acquisition radars, early detection of blunt objects with large radar cross-sections can occur a thousand miles or more from the point of interception. Even with designs of low radar cross-section, early detection by these powerful radars (e.g., those defined in the ABM treaty) takes place at distances of hundreds of miles. However, reducing the radar cross-section of missiles eliminates the ability of lesser radar systems (e.g., most SAM radars) to function as ABMs, and makes it easier to protect the missiles with chaff, decoys, and jammers.

SOVIET ABM TECHNOLOGY SINCE THE ABM TREATY

In the U.S., ABM research efforts after 1972 were placed under various informal, but nevertheless effective, Congressional enjoinders

against proceeding too far toward engineering development. In contrast, Soviet R&D was perceived in the U.S. as being much more oriented to working toward engineering prototypes and final production models.

Soviet work included improvements in high-altitude interceptor missiles as well as the development of a new high-acceleration interceptor, broadly similar to the U.S. Sprint, for lower altitude kills. Extensive R&D on phased-array radar technology was conducted. Prototypes of transportable ABM radars (in contrast to mobile ones deployed on a vehicle—which are prohibited by the ABM treaty) were tested. The Soviet components under development were assessed by the U.S. military as providing not only the potential for upgrading the Moscow ABM system, but also for the rapid deployment of a nationwide system. The latter possibility is often described in the West as a potential “breakout” from the ABM treaty with or without the six-month notification required for formal withdrawal.

In addition to the extensive R&D on conventional ABM systems, the Soviets appear to have carried out large-scale and costly investigations into directed energy weapon technology, including both lasers and particle beams. However, with the limited information we have on the kind of overall system into which directed energy components might fit, it is difficult to predict the applications for which such devices are intended.

Modernization of the Moscow System

The Moscow ABM system has been in continuous operation ever since its initial deployment in the early 1970s. Several years ago, it became apparent that major modifications to the Moscow system were in the offing, and the Soviets subsequently announced that they would be dismantling elements of the existing system. It now appears that a two-layer system is being deployed, with high-acceleration missiles for low-altitude interception augmenting improved Galosh-type high-altitude interceptors at new sites. The new missiles are being placed in silos, thereby reducing their vulnerability, a partial remedy to one weakness of the original system. New engagement radars at the missile sites are also anticipated. It appears the number of high- and low-altitude interceptors on launchers will reach the total of one hundred permitted by the ABM treaty.

In parallel with these developments, a new large multi-face phased-array radar—commonly referred to as the Pushkino radar—has been under construction in the original Moscow ring. This is similar to, but larger than, the missile site radar once deployed by the U.S. as part of the Sentinel/Safeguard system. This radar may be used to perform a variety of functions for target acquisition and tracking, decoy discrimination, and battle management.

In recent years, the Soviets have been constructing a set of five large phased-array radars on the periphery of the country, and a sixth is under construction in the interior. Except for the latter, these have been construed as being peripheral early-warning radars permitted by the ABM treaty. However, inherent in modern radars of this type is a capability for serving ABM battle management roles if properly supported by (intrinsically unobservable) control, data processing, and communication functions. (It should be noted that the U.S. is, at the same time, deploying a new set of peripheral phased-array radars designated “Pave Paws” to improve warning against SLBM attacks.) Extensive coverage of the approaches to the western part of the Soviet Union, in an arc from the Kola Peninsula to the northwest around Siberia and down to the Caucasus, is provided by these radars in combination with the earlier peripheral radars. The Defense Department has expressed concern that this radar network could be used to support ABM deployments well outside the present Moscow ring, especially in connection with a possible rapid deployment of an expanded ABM system in the event of a breakout from the ABM treaty. However, since large radars similar to these are used for tracking satellites, there is always some uncertainty as to the primary purpose of such installations.

U.S. BMD RESEARCH SINCE THE ABM TREATY

Even though the U.S. decided not to maintain an ABM system at the Grand Forks ICBM missile field in North Dakota, as permitted by the ABM treaty, research on ABM technologies continued throughout the 1970s, concentrated particularly in two areas. The first was the development of more effective and less costly technology for defending hardened sites, such as ICBM silos or command-and-control centers. This program received a great deal of interest at the time that the Carter administration was considering a mobile basing system of

multiple shelters for the MX missile. However, President Reagan's decision in 1983 to base the MX in existing Minuteman silos lessened interest in this type of mobile, hard-site defense.

The other area of R&D that has been pursued vigorously since 1972 is exemplified by the Homing Overlay Experiment. This was an effort to develop the technology for discriminating decoys at high altitudes using long-wave infrared sensors, either airborne or rocket-launched, and for developing non-nuclear-kill interceptors using long-wave infrared seekers. The culmination of this effort was the successful interception and destruction of a Minuteman-launched missile by an interceptor missile on June 10, 1984. This area of R&D is likely to be of increasing interest as a result of the SDI program.

"Unconventional" BMD: Early Concepts

Even in the 1950s, concepts different from those derived from the air defense tradition were being considered for defense against ballistic missiles. The Department of Defense was looking into so-called "exotic" technologies such as particle beams, and though these technologies were relatively immature at the time, research in such fields was being pursued for a variety of military applications, including BMD.

One program, mounted twenty-five years ago, was project BAMBI (ballistic missile boost intercept). This program foreshadowed the modern interest in using space-based weapons to intercept ICBMs in their initial boost phase, during which the rocket boosters emit infrared waves. The proposed system contemplated using rocket-propelled interceptor missiles on space platforms, in conjunction with sensors, to detect missile launch and to enable the interceptor missiles to home in on the ICBMs. Despite extensive studies, however, the Defense Department concluded in the 1960s that the state of technology did not permit a reliable and effective system. However, the High Frontier study of 1982 revived the BAMBI concept as the linchpin of a proposed new defense-oriented strategy.

By the 1970s, increased attention was also being given to the military applications of lasers and neutral particle beams for both tactical missions such as defense of naval forces, and for space-based BMD. During the Carter administration, there were debates within

the Defense Department and Congress on the priority to be given BMD in the high energy laser program, and these debates spilled over into the early years of the first Reagan administration. Although these internal debates were effectively muted by President Reagan's 1983 Star Wars speech, they have not disappeared entirely.

The types of lasers being investigated by the SDI include not only advanced types of chemical lasers, but also free-electron and excimer lasers capable of generating shorter wave-lengths that lend themselves to smaller and simpler optical systems for producing high-intensity beams. Also under study in the Department of Energy laboratories are lasers powered (or "pumped") by nuclear weapon explosions that generate beams of X-rays. There is currently considerable difference of technical opinion on how well and how soon such devices might be incorporated into effective ABM weapons, especially when countermeasures are considered.

THE U.S. STRATEGIC DEFENSE INITIATIVE

President Reagan delivered his so-called "Star Wars" speech on March 23, 1983, calling for a national effort to move from a strategic deterrence policy based on offensive weapons alone to one more strongly based on defensive systems. Although the speech was general in nature, its direction was clear and it immediately evoked a controversy. The most compelling of the arguments against the president's proposal seemed to be over the question of whether such a system of the kind envisioned—even if it would "work" in a technical sense—could really be effective in enhancing national security, rather than simply causing a new and dangerous escalation of the strategic arms race.

The Defense Department, in response to the president's direction, initiated two independent but related studies; one on technology and systems, under Dr. James Fletcher, and the other on policy, under Dr. Fred Hoffman. The major recommendation of the Fletcher study was for a long-term R&D program on ballistic missile defense, only the first five years of which were described in any detail. No specific BMD systems were selected for ultimate deployment, but promising new technologies and system components were identified. Decisions about further R&D on system development for deployment would be made after the initial five years of effort. Although the tone of the

recommendations was optimistic as to the likelihood of technical success, there were no firm predictions of when such success might be achieved for various system alternatives.

The Hoffman study addressed the policy implications of a U.S. ABM deployment in such areas as the U.S.-USSR strategic balance, the stability of deterrence, initiatives and responses of the USSR, and effects on relations with allies. The study concluded that deployment by the U.S. of BMD systems would be favorable in most respects, or at least preferable to other alternatives. The recommendations of the Hoffman study, in contrast to the Fletcher study, placed emphasis on the desirability of early deployment of BMD systems, even though their projected effectiveness would be considerably below that called for in the Fletcher study and implied in the president's speech.

The Department of Defense responded to these studies by establishing a new organization, the Strategic Defense Initiative (SDI), to carry out the expanded R&D program as recommended in the Fletcher study, although initially at a somewhat reduced level of funding. The debate on BMD will undoubtedly intensify as the program proceeds, and as funding requirements increase substantially in the next few years.

* * *

To some extent, the issues in the current debate over strategic defense do not differ from those of the ABM debates of the 1960s. As was the case then, there are important questions concerning technical feasibility and cost estimates of systems employing new technologies. These are important because one of the issues that must be decided is whether new technologies such as lasers and particle beams will make it possible to reverse dramatically the unfavorable cost-exchange ratios that have always burdened defensive systems. Closely related to this is the question of countermeasures and countertactics; of whether an opponent can overwhelm or negate a defensive system relatively easily and cheaply.

One of the new issues in the debate is that many of these new BMD systems would have to be deployed in space in order to be effective against Soviet missiles right after they are launched. However, space systems may be particularly vulnerable to countermeasures and direct attack, so their survival is a particularly critical issue.

The larger issues, however, remain primarily in the areas of policy and strategy. Can a BMD system change the reality of offense dominance brought about by the overwhelming destructive power of nuclear weapons? Will the uncertainty brought about by BMD efforts deter the offense, or will it simply lead to offsetting increases in offensive forces? On the other hand, can the U.S. run the risk of not proceeding with its BMD efforts, given that the Soviets may take the initiative and deploy them anyway? Finally, what is the role for arms control in avoiding a destabilizing BMD competition? In the coming months and years, these fundamental questions will need to be resolved if strategic defenses are to play an important part in promoting stability and deterring war.

REFERENCES

For more information on the technology and politics of ABM efforts in the 1960s and 1970s, see: Benson Adams, *Ballistic Missile Defense* (New York: American Elsevier, 1971); *ABM Research and Development at Bell Laboratories: Project History*, a report by Bell Laboratories, Whippany, N.J. (U.S. Army Ballistic Missile Defense Systems Command, 1975); Abram Chayes and Jerome B. Weisner, eds., *ABM: An Evaluation of the Decision to Deploy an Anti-ballistic Missile System* (London: Macdonald & Co., 1969); Fred Kaplan, *The Wizards of Armageddon* (New York: Simon and Schuster, 1983); Roger P. Labrie, ed., *SALT Handbook* (Washington, D.C.: American Enterprise Institute, 1979); Robert S. McNamara, *The Essence of Security: Reflections in Office* (New York: Harper & Row, 1968); and Gerard Smith, *Doubletalk* (Garden City: Doubleday, 1980).

BMD Technologies and Concepts in the 1980s

THE PUBLIC DEBATE CONCERNING strategic defenses against nuclear weapons, seemingly laid to rest by the 1972 ABM treaty, resurfaced in the early 1980s. This resurgence of interest was brought about, in part, by technological advances in a number of different fields: new possibilities for weapons systems employing laser and particle beams and kinetic energy projectiles, along with advances in guidance and sensing systems, optics, and computer processing seemed to make ballistic missile defense a more attractive and realistic proposition than it had been in the 1960s and 1970s.

This chapter will review how these new technologies might be incorporated into a multilayered BMD defense system of the sort being studied by the Strategic Defense Initiative. (For a more detailed assessment of these new technologies, see Appendix A.) Because the SDI is still in the research stage, we will not attempt to evaluate the ultimate effectiveness or final costs of such a system. Instead, we will focus on the potential strengths and vulnerabilities of the technologies that it would employ. We will be concentrating in this article on ballistic missile defense, although we emphasize that defense against other nuclear weapons delivery systems, such as manned bombers and cruise missiles, will also need to be addressed if the goal of a truly perfect defense is to be realized.

Before examining the BMD technologies and basing modes currently under consideration, it will be useful to review the flight stages of a ballistic missile in order to determine the tasks facing the various tiers of a multilayered BMD system.

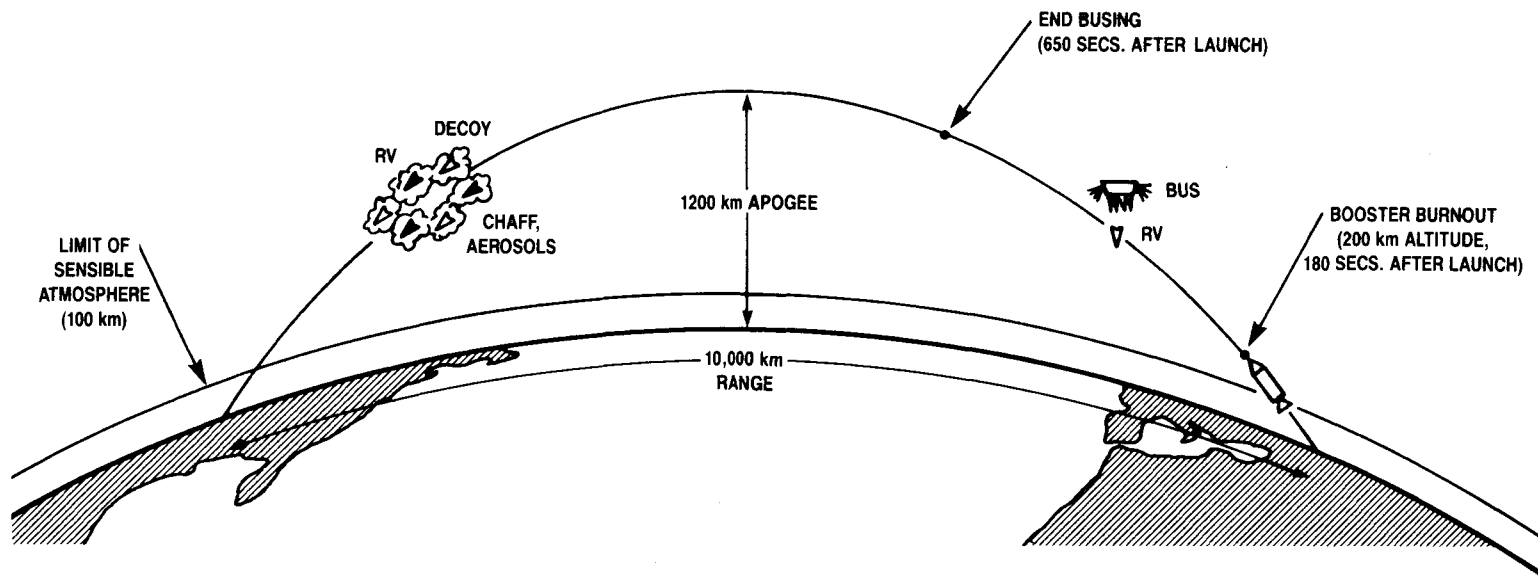


Fig. 1 Phases of Flight for an ICBM with Booster Characteristics Similar to the U.S. MX Missile

PHASES OF ICBM FLIGHT

The flight of a land-based intercontinental ballistic missile (ICBM) would follow a trajectory over the Arctic from one superpower to the other, last 25 to 30 minutes, and cover approximately 10,000 kilometers. When equipped with multiple warheads (MIRVs), the ICBM would have four phases of flight: a boost phase, during which large rocket boosters accelerate the missile to a velocity of seven kilometers per second; a post-boost phase, during which the missile deploys its warheads and decoys; a mid-course, where the warheads and decoys follow a ballistic trajectory through the vacuum of space; and a terminal phase, during which the warheads reenter the atmosphere (the decoys having been burned up, or slowed by friction) and descend toward their targets (see figure 1).

Unlike the ABM systems of the 1960s, which consisted only of terminal defenses, a multilayered BMD system would seek to attack enemy missiles during all four phases of flight. The ability to destroy ballistic missiles along the entire flight path, but especially during boost-phase before the missile has released its warheads, is what gives the multilayered BMD system its great conceptual attraction.

The same four phases of flight also characterize the flight of a MIRVed submarine-launched ballistic missile (SLBM), but SLBMs have particular characteristics that pose greater difficulties for the defense. Whereas the locations of ICBM silos are known with precision, submarines are moving and submerged. The uncertainty of where SLBMs would be launched forces BMD sensing systems to search a much larger area than it needs to for incoming ICBM warheads. Also, submarines can approach an opponent's coast and launch the SLBMs from within a few hundred to a few thousand kilometers, shortening the SLBM flight time to anywhere from seven to fifteen minutes. Finally, SLBMs can be given a flattened trajectory, making it more difficult for space-based BMD systems to target them.

CONCEPTS OF A MULTILAYERED BMD SYSTEM

Boost-phase intercept

The boost phase of currently deployed ballistic missiles lasts approximately three to five minutes for ICBMs and two to three minutes for SLBMs. For ICBMs, this means that the missiles will still be over

the Soviet Union as they begin to release their warheads, so a BMD system would have to be deployed either totally or partially in outer space in order to have a clear line of fire.

Missiles in boost phase are particularly vulnerable to destruction by a BMD system for two reasons. First, the missile booster is a large and fragile target, easily damaged by directed energy weapons (lasers, particle beams) and kinetic energy projectiles. Second, the flame emitted by the booster rockets gives off intense infrared radiation, providing space-based defense satellites with a fairly accurate fix on the missile's location. This same infrared radiation is what provides certain U.S. and Soviet satellites with early warning of an enemy attack.

There is a clear and powerful advantage to destroying ICBMs in boost phase, as destroying a single missile will result in the destruction of all the warheads and decoys on that missile. Given that current ICBMs and SLBMs carry anywhere from three to fourteen warheads and might carry one hundred decoys, successful boost-phase intercept can give a BMD system important leverage over the offense by substantially reducing the number of warheads and decoys that will confront the mid-course and terminal defense systems.

On the other hand, the Soviet Union could take steps to reduce the vulnerability of its missiles during boost phase. One means would be to shorten the duration of boost phase so that the missile releases its warheads and decoys while still in the earth's atmosphere, where many BMD weapons (X-ray lasers, particle beams, and kinetic energy projectiles) either cannot penetrate, or are ineffective. The MX missile is reported to have a boost phase of 180 seconds, releasing its warheads just outside the atmosphere at an altitude of 200 kilometers. Much shorter boost phases (50 seconds and 90 kilometers) are judged feasible, with only limited adverse effects on missile weight and performance. Missile vulnerability during boost phase could be further reduced by shielding the ICBM against lasers and particle beams, rotating it so that these directed energy beams are not allowed to deposit their energy on one particular spot, or by greatly increasing the number of real or dummy ICBMs that would have to be targeted.

Post-boost phase

The post-boost phase of an ICBM or SLBM begins when the final rocket booster has separated and fallen away from what is known as

the MIRV "bus," a small platform on top of the missile carrying the warheads and decoys. Depending on the number of warheads and decoys, this phase will last approximately two to five minutes, and can occur at altitudes of 100 to 1000 kilometers. During this period, small engine thrusters make slight corrections in the angle of the bus, allowing the warheads to be sent along predetermined trajectories toward their targets.

If a space-based BMD system attacked the MIRV bus during the post-boost period, it could hope to destroy a number of warheads and decoys along with the bus. On the other hand, the Soviet Union could shorten this phase through a technique known as "cluster release," in which all the warheads and decoys are ejected nearly simultaneously, with only a slight loss of warhead accuracy.

Mid-course phase

Once the warheads and decoys have been released, they travel through space for approximately 15 to 20 minutes (7 to 10 minutes for SLBMs) before reentering the atmosphere. There are now as many as fourteen (and, in the absence of arms control limitations, potentially twenty to thirty) warheads and one hundred or more decoys for every ballistic missile launched. The use of decoys to increase greatly the number of possible targets is especially effective, because in the vacuum of space the trajectories and velocities of warheads and decoys will be indistinguishable. These decoys could consist of suitably shaped pieces of metal or plastic, or aluminized balloons, which will appear to BMD sensing systems as actual warheads. In addition, the release of fragments of metal wire, called chaff, or clouds of aerosol could hide the actual warheads by overwhelming the BMD sensing systems.

A more fundamental problem with mid-course interception concerns how to locate precisely these warheads and decoys in the first place. Unlike missile boosters with their infrared signatures, warheads and decoys do not give themselves away to space-based satellite sensors. A BMD system must either search for the warheads and decoys, which emit modest amounts of infrared radiation and reflect the earth's faint infrared light, or it must illuminate these objects by reflecting radar waves or lasers off them.

One means being investigated by the SDI for reducing the problem of locating targets, and then distinguishing warheads from decoys,

involves what is known as “birth-to-death tracking.” A BMD sensor would lock on to a real warhead as it is being deployed from the MIRV bus and track it continuously through the mid-course and terminal phases of flight. The difficulty with birth-to-death tracking is that the release of decoys, chaff, and clouds of aerosol could interfere with the process. Moreover, warheads could be hidden inside decoys such as aluminized balloons, further complicating the problem of distinguishing actual warheads from harmless decoys. Finally, the initial identification of warheads as they are being released from the MIRV bus could be complicated by the use of a shield or the emission of smoke.

Terminal phase

The final portion of ballistic missile flight is the terminal phase, during which the warheads and decoys reenter the earth’s atmosphere at an altitude of about 100 kilometers and approach their targets. Although the terminal phase is short, lasting only thirty to sixty seconds, there is no problem with target identification. Upon entering the atmosphere, air friction will burn up the lighter decoys (balloons) and slow the heavier ones, leaving only the warheads themselves traveling at a high velocity.

Advances made since the 1960s in radars and other sensors, computer processing, and the accuracy of BMD interceptors has made terminal defense a much more viable proposition than it was twenty years ago. In particular, striking improvements in radar and computer technology now make it possible to use non-nuclear interceptors instead of the nuclear warheads that were part of the Sentinel and Safeguard ABM systems, and which are still found in the Soviet Galosh ABM system around Moscow. An illustration of this is the Homing Overlay Experiment carried out by the U.S. Army in June 1984, in which a steel mesh projectile launched by a Minuteman booster destroyed a dummy warhead at an altitude of more than 150 kilometers over the Pacific Ocean. Other possibilities include the “swarmjet,” a weapons system that would fire thousands of small darts at incoming warheads.

Yet warheads can be provided with devices to foil a terminal defense. One such method is known as “salvage fusing”—the warhead would detonate automatically when it sensed an approaching BMD interceptor such as a missile, or when it is the target of a

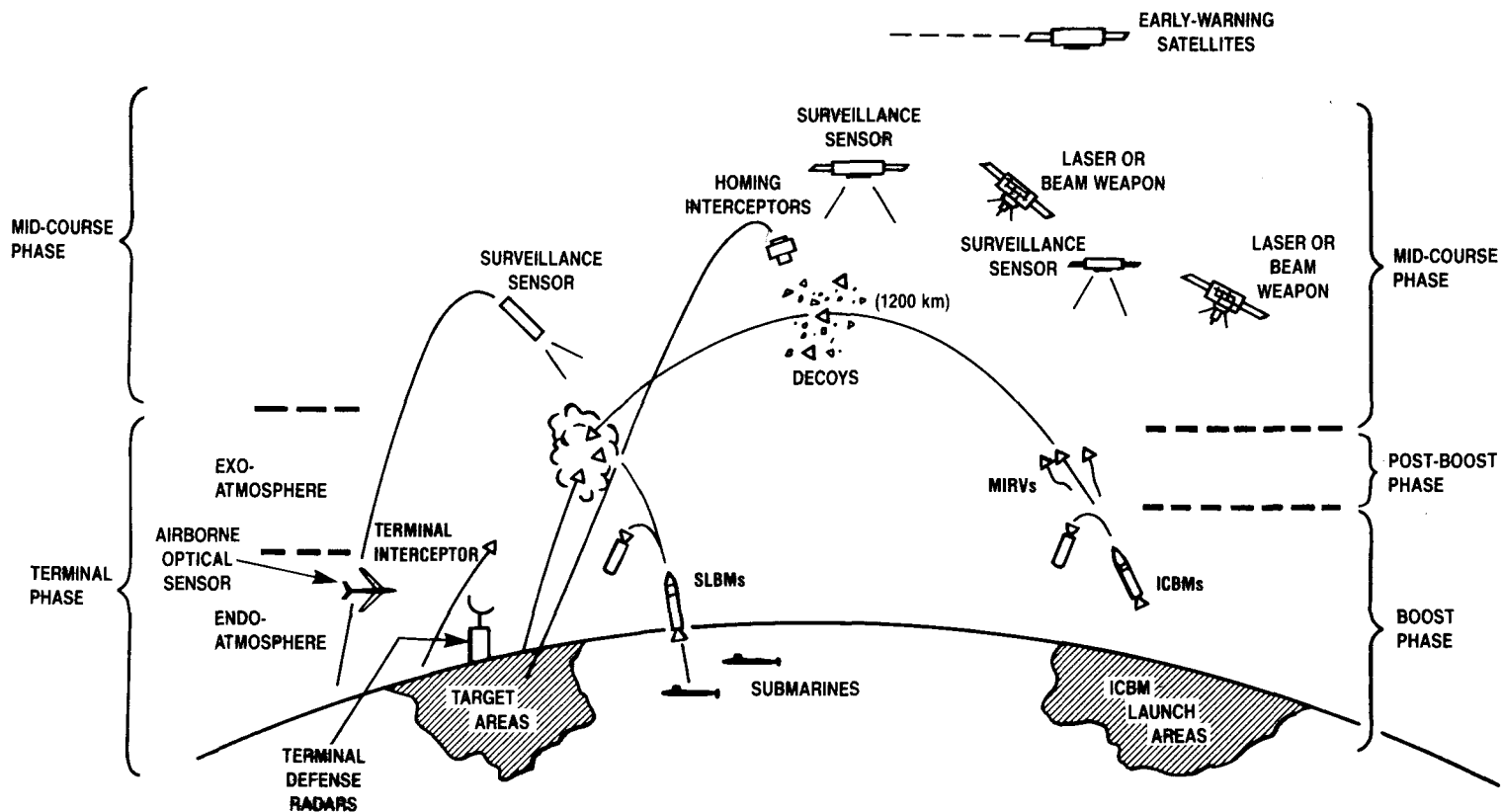


Fig. 2 Multilayered BMD System

laser beam. The use of maneuvering warheads (MaRVs) is another possibility. Warheads that appear to be headed for one target as they reenter the atmosphere could, using small winglets or specially configured noses, suddenly veer off at hypersonic velocities toward completely different targets.

The primary difficulties facing terminal defenses, however, are not so much technical as conceptual. To be a fully effective tier of a multilayered BMD system, terminal defense must be able to protect both hardened military targets (point defense) and soft targets such as cities and industry (area defense). A defender can tolerate destruction of many of his missile silos so long as a sufficient retaliatory force survives. A successful defense of cities and industry will have to be nearly perfect, however, since even the detonation of a few nuclear warheads high above cities will cause immense destruction. Figure 2 depicts the concept of a multilayered BMD system.

NEW BMD WEAPONS TECHNOLOGIES

Much of the public focus in the debate over strategic defenses has centered on the promise held out by new BMD weapons technologies, especially the so-called *directed energy weapons* (DEW).¹ These include various types of laser and particle beams, which travel at or near the speed of light (300,000 kilometers per second). Yet creating a promising DEW candidate will be a challenge: it will involve developing a laser and/or particle beam of sufficient intensity and accuracy to deposit large amounts of energy on small areas of rapidly moving ballistic missiles and warheads from great distances.

Lasers

The term “laser” is an acronym, standing for *light amplification by the stimulated emission of radiation*. Essentially, lasers can provide very narrow beams of coherent light with sharply defined wavelengths.

Four types of lasers are currently under consideration for BMD missions: infrared chemical lasers, electrically driven ultraviolet lasers, free-electron lasers, and X-ray lasers produced by nuclear explosions. These laser beams could destroy a missile booster or a warhead in one of two ways. Chemical, ultraviolet, and free-electron lasers (all known as optical lasers, being similar to visible light rays)

would use a concentrated beam of light to burn into the missile “skin.” The X-ray laser works differently, penetrating only a very thin layer of the booster skin, but initiating a shock wave that could destroy the missile’s internal components or knock it off course.

In the design of optical lasers, the problem consists in achieving suitably intense beams of parallel light and aiming these at targets thousands of kilometers away. A large and precisely machined mirror, perhaps ten meters across, or a system of mirrors, would produce a beam of concentrated light that would spread to only a meter diameter after having traveled thousands of kilometers through space. Once the target is reached, the laser beam must focus on the same spot of the rapidly moving object for the several seconds needed to heat it sufficiently and destroy it.

Unlike optical lasers, X-ray lasers are created from the explosion of a nuclear weapon.² The incredibly high temperatures produced in a fraction of a microsecond by the nuclear explosion bring about a “lasing” action in a number of very thin metallic wires that are embedded in a plastic around the nuclear device. This lasing process then produces beams of X-rays, just before the nuclear explosion itself destroys the satellite battle station.

Because of their short wavelength, X-rays differ from other lasers in three important respects. First, unlike optical lasers, powerful X-rays cannot be pointed by mirrors. Second, the X-rays generated from the wires cannot be as tightly focused as optical lasers. This means they can only be used from moderately short distances (a few thousand kilometers), and probably not from geosynchronous orbit (36,000 kilometers above the earth). Third, the soft X-rays do not penetrate the earth’s atmosphere, and thus can be used only against missiles or warheads traveling through the vacuum of space.

On the other hand, a nuclear-powered X-ray laser device will be much lighter than optical laser battle stations, because the latter require large mirrors and more fuel. As will be seen below, this makes X-ray lasers a potential candidate for so-called “pop-up” systems, in which the X-ray laser would be lofted into space on top of a ballistic missile.

Particle Beams

Research is also being carried out on *particle beams* produced by particle accelerators (atom-smashers). These highly energetic beams

are familiar research tools in physics laboratories. If the particles (hydrogen ions, for example) are accelerated to nearly the speed of light, they can penetrate deeply into material targets. Yet charged particle beams are not suitable for transmission over large distances because they are deflected by the earth's magnetic field. Scientists have instead proposed using neutral hydrogen beams, which might be obtained by accelerating negative hydrogen ions and stripping off the extra electron.

Particle beams have an advantage over lasers in that their deep penetration into the target could destroy the electronics and guidance systems of the MIRV bus. Another advantage is that the beam from the accelerator can be steered by electric and magnetic fields, without moving the accelerator itself; this is important if several targets are to be attacked in quick succession.

A main problem facing weapons designers is to produce particle beams of sufficient intensity and small divergence from accelerators that are lightweight enough to be lofted into space. In addition, particle beams have very limited ability to penetrate the earth's atmosphere. Collision with air molecules will strip the electron off the hydrogen atom, converting the neutral into a charged beam and causing it to fan out in the earth's magnetic field. This effectively destroys the lethality of the beam. Particle beams are therefore of only limited usefulness against missile boosters, especially if these are designed to release their warheads while still in the atmosphere.

Kinetic Energy Weapons

The final type of BMD weapon is the *kinetic energy* weapon. This is typically a rocket-propelled weapon that accelerates small projectiles. As with the F-15 anti-satellite weapon, these projectiles "home in" on the target using infrared sensors for guidance and tiny rocket thrusters to change direction.

These projectiles can destroy a booster or warhead simply by high velocity impact. The velocity of the missile and/or warhead actually contributes to its destruction; the projectile hurtles towards its target either head-on or at right angles, penetrating it to a depth many times its own length. The weapons themselves would be carried by a large satellite, and fired by either rockets or, possibly, electromagnetic railguns.

Kinetic energy weapons have two drawbacks when it comes to boost or post-boost intercept. Because they are very much slower than directed energy weapons, they cannot travel very far during the first few minutes after enemy missiles have been launched. Moreover, if the target is still within the earth's atmosphere, friction caused by the projectile will heat the surrounding air and interfere with the infrared guidance system.

Accordingly, kinetic energy weapons are considered more appropriate for mid-course defense in the vacuum of space, where there is also more time to engage the target. Such weapons could be either ground-based or space-based. If space-based, they would have an advantage over directed energy weapons in not needing such fragile ancillary equipment as large space mirrors. Kinetic energy weapons are also very suitable for terminal defense, at least of hardened military targets, after the warheads have reentered the atmosphere.

DEPLOYING BMD SYSTEMS IN SPACE

Because of the curvature of the earth, and the fact that Soviet ICBMs will only be 100 to 400 kilometers above the USSR during boost phase, it is only from space that a BMD system will have a clear shot at missiles rising from Soviet silos. For this reason, BMD systems will either have to be on permanent station in space, on orbiting satellites, or be launched ("popped up") into space on notice of an attack.

In devising a constellation of orbiting space-based BMD platforms, however, a second physical constraint intrudes: only in geosynchronous orbit will a satellite remain over a given spot on earth during its entire orbit. Given the tremendous distance from a geosynchronous BMD platform to its target, it would be preferable to station the platforms just above the earth's atmosphere (at altitudes of 500 to 1000 kilometers). However, BMD platforms in low earth orbit will be circling the earth once every 100 minutes or so, and do not remain stationary over the same spot (e.g., an enemy's missile field) throughout their revolution. This means they would only be within range of enemy missile silos once or twice a day, necessitating an increase in the number of space platforms required for continuous coverage. This is known as the "absentee problem": of a certain number of BMD platforms orbiting the earth, only a fraction will be available at any given moment to attack ICBMs.

In designing a space-based BMD system, then, there are trade-offs that must be made between the placing of weapons in geosynchronous orbit (which demands effectiveness over tens of thousands of kilometers), and low-earth orbit (where dozens if not hundreds of platforms would have to be placed in order to ensure a sufficient number within effective range of Soviet silos and submarines).

There have been many preliminary proposals for the BMD systems mentioned above—among them, stationing infrared lasers in low-earth orbit; deploying ultraviolet (excimer) lasers in geosynchronous orbit; and basing the excimer laser itself on the ground and using a set of relay mirrors in both geosynchronous and low earth orbit to target the rocket booster.

The use of “pop-up” BMD systems, consisting of X-ray lasers launched into space quickly on top of ballistic missiles, is an alternative to maintaining BMD systems continuously in orbit. Here again, however, physical constraints intervene. First, because the earth is round, any pop-up system will have to be deployed fairly close to the Soviet Union in order to be effective for boost-phase intercept. The reason for this is that the popped-up system will have to climb very quickly to a point far above the atmosphere so as to have a clear line of fire against the enemy missile before that missile releases its warheads and decoys. Even if the X-ray laser could be launched nearly simultaneously with the firing of Soviet ICBMs, this BMD system would still have to be deployed within a few thousand kilometers of the Soviet silos. This means putting pop-up systems on submarines, and deploying the submarines in the Indian Ocean, the eastern Mediterranean, the Arctic Ocean, or the Sea of Okhotsk. Of course, deploying submarines so close to the Soviet Union could make them vulnerable to Soviet anti-submarine forces. Moreover, pop-up systems could still be countered by the development of fast-burn ICBM boosters, even if these release their warheads above the atmosphere. For instance, if the boost phase can be completed in 130 seconds, even a system located 4000 kilometers from the missile silo could not reach a high enough altitude in space to get a direct line of fire at the ICBM.

Command-and-Control of BMD Systems

One of the major tasks facing a multilayered BMD system will be the creation of appropriate command-and-control capabilities (see the

essay in this volume by Charles Zraket). The range of tasks facing a BMD system will include acquisition and tracking of targets, discrimination of warheads from decoys, actual firing of the directed energy or kinetic energy weapons, and follow-up assessment of whether or not the target was destroyed. All these tasks must be coordinated by a reliable system of computers and high-speed data links. The issue of reliability is especially important given the issue of automated response, i.e., the fact that there may not be enough time for a president to give the command to destroy Soviet missiles during boost and post-boost phase.

Computers, which could be stationed both in space and on the ground, would have to be capable of analyzing and transmitting huge amounts of information reliably and securely. More important than the computer hardware itself will be the extremely sophisticated software needed to coordinate a BMD defensive network. Many experts believe that the task of developing this software, and ensuring its reliability so that the BMD system works perfectly the first time in conflict, will be even more difficult than building the actual BMD components.

Another important criterion for the success of a multi-layered BMD system is the ability of each layer to “hand over” those targets not destroyed to the next layer. Each successive layer must be “told” by the previous one, through use of a battle management system, which nuclear warheads have been destroyed and which have not. Given that lasers and particle beams do not always physically destroy their targets but sometimes merely damage internal components, the problem becomes more difficult. In short, the tiers of a BMD system will not act independently, but must be fully integrated by the command-and-control system to perform their intended functions.

COUNTERMEASURES

Resolving the related problems of offensive countermeasures and BMD system survivability will be even more important than demonstrating the actual technical feasibility of BMD weapons and other systems components, or ensuring the efficiency of the command-and-control system. One point to consider is that, while many of the technological and systems problems associated with new BMD concepts are far from being solved, a large number of different types of

countermeasures are available now. Many of these countermeasures are far less technically sophisticated than the BMD systems they will try to overcome, and thus are less expensive as well. It may well be that, as new BMD systems are developed, methods of negating many of these countermeasures will be found. On the other hand, new countermeasures will almost surely be developed as well, leading to a continuing competition between offensive and defensive systems.

A second point to consider is that by their very nature BMD systems are reactive: they will be designed to work on short notice, at a time and place of the opponent's choosing, and against a wide range of possible countermeasures. This gives the offense an additional advantage, for it may choose which of the numerous available countermeasures it wishes to employ, while the defense will have to be prepared to deal with all of them. On the other hand, one of the conceptual attractions of a multilayered BMD system is that, in many cases, a countermeasure that is effective against one particular BMD tier will not work against another tier, thus increasing the number of countermeasures an attacker must have at his disposal to ensure the ability of his warheads to penetrate.

In considering the broad range of countermeasures, it is useful to group them into three categories of passive, active, and threatening.³ Passive countermeasures are those that seek to aid the penetrating ability of incoming missiles and warheads without directly attacking the BMD systems. There are numerous types of passive countermeasures, most of which are designed to work against a particular tier of a BMD system. Examples include: fast-burn boosters and methods of shielding the booster (against boost-phase defenses); a cluster release of warheads and decoys from the MIRV bus (against post-boost defenses); the use of aluminized balloons, chaff, and clouds of aerosol (against mid-course defenses); and salvage fuzing and maneuverable warheads (against terminal defenses).

Active countermeasures are those that attempt to interfere directly with the components of a BMD system or to destroy them altogether. In the 1960s, it was recognized that the large ground-based radars associated with terminal ABM systems were both vulnerable to direct attack and could be blinded by a few nuclear explosions very high in the atmosphere ("radar blackout"). These types of "defense suppression" tactics could pose an even greater threat to a space-based BMD

system. Because the defense's sensors, space mirrors, command-and-control systems, and weapons platforms will be traveling in predictable orbits, such satellites, especially in low earth orbits, will be easier targets than the ballistic missiles and warheads they are designed to detect and destroy. In addition to "blinding" and "radar blackout," existing U.S. and Soviet ASATs, as well as small space mines, could be used to destroy BMD satellites. The Soviets could also use their Galosh nuclear BMD interceptors to punch holes in a space-based BMD system. Even the release of a swarm of small steel pellets in the path of an oncoming BMD satellite or unprotected space mirror would be sufficient.

Various methods are being investigated to enhance the survivability of satellites, including hardening them, giving them maneuvering ability for evasive action, and even deploying defensive satellites (DSATs) to actively protect them. While such measures are certainly feasible, they would impose extra costs and constraints on the defensive system. Hardening and maneuverability would add to the size and complexity of the BMD satellites, while deploying defensive satellites would be costly and increase the command-and-control problems of the overall system.

Other types of countermeasures consist of those that interfere directly with the complex operations of the BMD systems without necessarily damaging the system itself. For example, decoys traveling through space can be equipped with radar transmitters that send out false signals to confuse BMD sensor systems. In addition, both decoys and actual warheads can be given the ability to maneuver during mid-course in order to confuse passive tracking schemes that depend on these objects remaining on a ballistic trajectory. This type of maneuvering capability would, as we have seen, also complicate the task of terminal BMD systems.

The final category of threatening countermeasures is especially worrisome. Along with the active and passive means described above, an opponent could simply increase his offensive forces in an effort to overwhelm a multilayered BMD system. In essence, this is what happened in the early 1970s, when the U.S., followed by the Soviet Union, started adding multiple warheads (MIRVs) to their missiles so as to overwhelm the projected terminal ABM systems of the other side. Both sides could also build dummy silos and fake ICBMs that would look real to BMD sensor systems. Or, both countries could

deploy additional cruise missiles and other types of nuclear delivery systems against which BMD systems would be ineffective.

In sum, a good deal of attention will have to be given to the interaction of new BMD systems and countermeasures as they evolve.⁴ It will not be enough merely to demonstrate the technical feasibility of new BMD systems: we will need to ensure that such systems will be relatively invulnerable to direct attack or interference.

SDI EXPENDITURES AND COST-EFFECTIVENESS

Given that the SDI program is still in its early stages, it is difficult to estimate the final costs of deploying and maintaining a multilayered durable and effective BMD system. Tentative estimates that have been made range from \$100 billion to more than \$1000 billion (one trillion), but these must remain speculative until more is known of the configuration of the BMD system.

What can be said with some certainty is that deploying and operating strategic defenses against ballistic missiles, involving dozens if not hundreds of complex weapons platforms and sensing systems in space, extensive command-and-control networks, as well as numerous space vehicles to deploy and repair the system, will be a very expensive proposition. If comprehensive defenses against manned bombers and cruise missiles are deployed as well—an effort former Secretary of Defense James Schlesinger has estimated could cost \$50 billion annually—then the overall cost could well be prohibitive.

In the near term, the costs of the SDI research program are projected to increase sharply.⁵ For fiscal year 1986, the administration has requested \$3.7 billion, a 160 percent increase over 1985. There are doubts, however, concerning the ability of the individual SDI research programs to make profitable uses of such increases. Schlesinger, for example, has testified before Congress that military R&D programs normally should not expand by more than 35 percent annually, and that SDI funding of \$1.5 to \$2 billion for 1986 would be “ample.”⁶

If Congress does grant the administration's SDI funding requests, which is by no means certain, by fiscal year 1989 the SDI budget will be \$7.5 billion, or 16 percent of total Defense Department R&D funding, a significant amount. If one adds in projected 1989 spending

on other types of defense, such as anti-satellite weapons and air and civil defense, the total approaches \$12.4 billion.⁷

For the period 1985–89, then, the administration has requested \$26 billion for the SDI program, and upwards of \$40 billion for strategic defenses in general. By 1989, this level of investment will have created a large military and industrial constituency with a vested interest in accelerating the program, even if many of the proposed technologies should fall far short of expectation. By the early 1990s, once the SDI has moved from the research stage to the development and testing of engineering prototypes, the annual budget for strategic defenses could well be in the tens of billions of dollars.

The question of whether such expenditures will ultimately produce worthwhile defenses cannot be answered now. Yet, as Lt. Gen. James Abrahamson, the SDI program director, has noted, it must be proved that a strategic defense system is both technically feasible and affordable, i.e., that it will cost the U.S. “substantially less” to build the system than it will for the Soviets to counter it.⁸

The notion of cost-effectiveness is based on the relationship of the cost to the offense of ensuring the ability of its warheads to reach their targets, compared with the cost of developing, deploying, and maintaining a defensive system. The standard method for analyzing cost-effectiveness uses a marginal cost-exchange ratio that asks, in effect: what marginal improvements will the defense have to make to offset corresponding improvements in the penetrability of offensive forces? (See the essay by George Rathjens and Jack Ruina in this collection.) If it can be shown that, in all likelihood, a defensive system will suffer a negative cost-exchange ratio (i.e., that it will be cheaper for the offense to upgrade its forces than it will for the defense to negate those improvements), then a strong argument can be made against spending the money to develop and deploy the defense in the first place.

For instance, Defense Department studies of marginal cost-exchange ratios done in the mid-1960s, before the actual deployment of U.S. ABM systems, demonstrated convincingly that Soviet offensive forces would enjoy anywhere from a three-to-one up to a ten-to-one cost-exchange advantage over a U.S. ABM defense. In other words, for every dollar spent by the Soviets to ensure the penetrability of its warheads, the U.S. would have to spend from three to ten dollars to offset that improvement. As Alexander Flax notes in his paper, this

negative cost-exchange ratio for the defense figured importantly in arguments against the deployment of extensive ABM systems.

Whether or not the leverage provided to defensive systems by boost-phase intercept will be able to reverse these ratios will depend greatly on the feasibility of Soviet boost-phase countermeasures, and the ability of the Soviets to attack a space-based BMD system directly. Paul Nitze, senior arms-control advisor to the Reagan administration, has stressed that the two criteria of BMD cost-effectiveness and survivability are crucial; that "if the new technologies cannot meet these standards, we are not about to deploy them."⁹

A second major issue regarding SDI expenditures concerns possible opportunity costs strategic defenses could pose for other U.S. military capabilities. Even if BMD systems turn out to be marginally cost-effective vis-a-vis Soviet offensive forces, the expenditure of hundreds of billions of dollars on strategic defenses (if this figure is correct) could impose severe constraints on other U.S. military programs. Any benefits the SDI would bring to enhancing strategic nuclear deterrence could be offset if the program draws funds away from the continued modernization of U.S. conventional military forces and weakens conventional deterrence between the superpowers. While the issue of opportunity costs will not become serious until the SDI has moved from R&D to testing and procurement, which will probably occur in the early 1990s, some thought must be given now to how strategic defenses will mesh with the entire range of U.S. military capabilities, both nuclear and conventional.

In sum, despite remarkable advances since the 1960s in BMD related technologies, there are major uncertainties surrounding the ultimate feasibility of deploying and maintaining strategic defenses against ballistic missiles. Even if many of the remaining technical obstacles are overcome in the areas of weapons systems, optics, sensors, and guidance systems, there will still remain the issues of countermeasures, survivability, cost-effectiveness, and the integration of strategic defenses with overall U.S. military capabilities.

ENDNOTES

¹See also Ashton B. Carter, *Directed Energy Missile Defense in Space* (Washington, D.C.: U.S. Congress, Office of Technology Assessment, April 1984); and Jeff Hecht, *Beam Weapons* (New York: Plenum Press, 1984).

- ²It has been widely reported that, although the X-ray laser concept provided much of the impetus for President Reagan's interest in BMD and for his "Star Wars" speech, X-ray laser weapons have currently fallen out of favor because they entail the explosion of nuclear weapons; see, " 'Star Wars' Technology: It's More than a Fantasy," *New York Times*, March 5, 1985, p. 1.
- ³See especially the section on countermeasures in *Space-Based Missile Defense*, a report by the Union of Concerned Scientists, (Cambridge: Union of Concerned Scientists, March 1984), pp. 45-52.
- ⁴The Defense Nuclear Agency (DNA), for example, plans to spend \$600 million over the next several years studying how the lethality of directed energy weapons and kinetic energy projectiles against rocket boosters and warheads could be offset by potential countermeasures the Soviets could employ by the year 2000. The DNA program, which will rely heavily on computer simulations, will look at six weapons candidates, including: ultraviolet lasers, excimer lasers, X-ray lasers, particle beams, kinetic energy projectiles, and microwaves. See Philip J. Klass, "Defense Nuclear Agency Directing Six-Year Lethality Assessment," *Aviation Week & Space Technology*, April 1, 1985, p. 65.
- ⁵One especially good analysis of short-term SDI funding is "Analysis of the Costs of the Administration's Strategic Defense Initiative 1985-1989," a staff working paper of the Congressional Budget Office (Washington, D.C.: U.S. Congress, May 1984).
- ⁶See "SDI Director Defends Rise in Research Funds," *Washington Post*, March 20, 1985, p. A12.
- ⁷See John E. Pike, "Paying for Star Wars—The Rest of the Picture," a staff research note of the Federation of American Scientists, Feb. 5, 1984.
- ⁸"Panel Told 'Star Wars' Needn't Breach Treaty," *Washington Post*, Feb. 28, 1985, p. A28.
- ⁹Paul Nitze, "On the Road to a More Stable Peace," speech delivered to the Philadelphia World Affairs Council, Feb. 20, 1985, p. 4.

The Strategic Defense Initiative

IN HIS WIDELY PUBLICIZED SPEECH of March 23, 1983, President Reagan speculated on a new approach to national security. He did not put forth a concrete proposal, but instead posed a question: "Would it not be better to save lives than to avenge them?" He called upon the scientific and technical community "to give us the means of rendering these nuclear weapons impotent and obsolete." The only specific activity he proposed immediately was "a comprehensive and intensive effort to define a long-term research and development program to begin to achieve our ultimate goal of eliminating the threat posed by strategic nuclear missiles." The president also speculated that this R&D effort "could pave the way for arms-control measures to eliminate the weapons themselves." On April 18, 1983, he signed a national security directive mandating two intensive studies that would develop a plan for program implementation beginning in fiscal year 1985. The purpose of one study was to consider the policy implications of defense technologies; the other study was to deal with the technology itself.

The president clearly caught many people by surprise by calling for these studies in his address. It would have been less disturbing had the studies been carried out quietly *before* the president made his specific program request in public. Yet, unusual as this exercise of presidential leadership might have been, it may have been the most effective way of galvanizing a large and diverse group of experts to leave their jobs and invest several months of time and effort in a controversial project. While I cannot profess to know the president's precise motivations, I can cite several factors that influenced many of us to

become involved in the technologies study. We were not only acutely aware of the restrictions existing on ballistic missile defenses (BMD) by the ABM treaty, but recalled the hope fostered by that treaty that our retaliatory forces would remain survivable. The United States stated in 1972 that the treaty would serve as the basis for "more complete limitations on strategic arms," and that "if an agreement providing for more complete strategic offensive arms limitations were not achieved within five years, U.S. supreme interests could be jeopardized. Should that occur, it would constitute a basis for withdrawal from the ABM treaty." The level of arms limitation that had been hoped for was not achieved. Instead, the Soviet Union's vigorous development and deployment of large ICBMs with multiple warheads now threatens our Minuteman missiles, with the result that our national interests are in greater jeopardy today than they were ten years ago.

In addition, the recent protracted search for a "survivable" basing mode for our MX missile had frustrated many of us who had worked in the strategic weapons arena. We began to feel that the continued buildup of Soviet forces was making the possibility of nuclear war all too real, and we believed that some solution would have to be found to the vulnerability of our land-based missiles. Nor can one work on weapons and be unaware, as well, of the strong, vocal, and broadly based freeze movement in this country that is calling for a halt to all further production and testing of nuclear weapons, or of the Catholic bishops' Pastoral Letter on War and Peace that expressed "profound skepticism about the moral acceptability of any use of nuclear weapons." Arms-control negotiations have been frustrated by the Soviet Union's resistance to significant reductions in nuclear weapons, and growing suspicion and mistrust on both sides had brought us to a new level of deterioration in Soviet-American relations. Indeed, the continued Soviet buildup of high-precision, short-reaction-time, offensive weapons had led to growing concern in the U.S. over the possibility of a Soviet preemptive strike and the effect this possibility would have on strategic stability. Many were beginning to question whether civilization could survive indefinitely in this condition.

Even before President Reagan's speech about the SDI, several public figures had been advocating revolutionary change in our approach to national defense. For several years, Senator Malcolm

Wallop (R-Wyoming) had vigorously supported a crash program to develop space-based lasers. His point of view had been expressed in publications, speeches, and proposed (but rejected) legislation dating back to 1979: "Technology now promises a considerable measure of safety from the threat of ballistic missiles."¹ His technologically optimistic point of view—undoubtedly known to the president—was exemplified by an open letter he wrote to the Senate following the president's speech, in which he offered to "integrate three mature technology programs into a space-based laser weapon demonstration as quickly as possible."²

Another voice was that of General Daniel Graham (retired U.S. Army), who presented the "High Frontier" proposal to deploy space-based rocket-launched projectiles to intercept boosters. This concept, he said, would "free America from the threat of Soviet ballistic missiles largely by using technology that was proven successful as far back as 1959."³ Finally, Dr. Edward Teller, who had advised the president on scientific matters for a number of years, urged the development of nuclear-driven directed energy weapons that "by converting hydrogen bombs into hitherto unprecedented forms and then directing these in highly effective fashions against enemy targets would end the MAD [mutual assured destruction] era and commence a period of assured survival on terms favorable to the Western Alliance."⁴

It was also becoming increasingly obvious that the Soviet Union was investing far greater resources on strategic defense than was the United States. The Soviets were continuing tests of their operational anti-satellite system, making improvements in their conventional Moscow BMD system capability, constructing a new large radar in the eastern Soviet Union that, according to the U.S. government, is "almost certainly a violation of the ABM treaty," and making large investments in advanced long-term research (such as ground-based lasers) that could be applicable to BMD.⁵ In addition, continued Soviet investments in anti-tactical ballistic missile development indicated the possibility of their establishing the type of infrastructure necessary for the rapid deployment of a nationwide defense system.⁶

While the Soviets were making substantial investments and clearly closing the technological lead that the United States had held ten years previously, the United States was continuing to pursue a low-level BMD research program, but without a well-defined under-

lying goal or strategy. Many of us in the weapons field believed that, because of continued starts and stops, changes in direction, disputes over accelerated or slow programs, and distribution of management among departments, military services, and agencies, the true potential of BMD had not been realized in spite of rather significant expenditures. We were aware that although technology had advanced considerably in the last ten years, our expenditures had not given us maximum returns on our investments.

Most of us who became involved in the technologies study did not feel that the president was urging us to pursue specific, short-term weapons development programs. Our understanding was rather that we were to initiate creative approaches that, although perhaps unavailable today or even in the near future, could someday provide entirely new and effective technological options that would “pave the way for arms control measures to eliminate the weapons themselves.”

Many of us also came to recognize that we were faced with the need for more than just technological achievements. We realized that solving what may be the most serious problem facing us today would demand breakthroughs in policy and strategy, as well as in technology. When the president initiated the technologies study, there were many unresolved issues and many questions on program goals and approaches that were still unanswered. These questions were very much before the president, his advisers, and the study teams when they met in Washington on June 2, 1983, to begin their deliberations.

Two policy study teams and one technology study team were formed as a consequence of the president’s national security study directive. The policy study group, which reported to Under Secretary of Defense for Policy Fred Ikle, was to examine “the impact of defensive technology on deterrence and arms control,” and was composed of a government team chaired by Franklin Miller plus a team drawn from outside consultants and chaired by Fred Hoffman. (This group is often informally referred to as the Hoffman panel.) The Defensive Technologies Study Team (DTST), of which I was a member, reported to Under Secretary of Defense for Research and Engineering Richard DeLauer. (Our group is informally referred to as the Fletcher panel, after its chairman, James C. Fletcher.) These three teams, which met separately and reported to different Defense

Department officials, conducted their studies independently throughout the summer and were only afterwards integrated, by a senior interagency group. The DTST was divided into six main technical panels consisting of more than fifty full-time people drawn from industry, national laboratories, and universities.⁷ Each panel held comprehensive reviews with hundreds of briefings, and after extensive deliberations prepared a report of its findings. Producing a consensus from a wide distribution of opinions required the individual members to examine and reevaluate their own views, as they worked alongside and compromised with others. An executive summary of the separate panel reports was also prepared that included the unified plans and budgets for two levels of research activity: one that would push ahead as fast as technological advances permitted, and the other that would proceed at a slower pace, set by limits on available funds. (As the executive summary is still classified, I will, in this article, be summarizing its contents for the general reader.)

The initial stage of the studies was the most difficult, involving as it did an attempt to clarify the goal that had been stated by the president, namely, to eliminate the threat of nuclear ballistic missiles. Should we pursue a nearly leakproof defense of our population, a less-demanding defense of our retaliatory forces, or some combination of increased defenses and arms control that would reduce the role of offensive forces? Should we emphasize readily available technologies as a hedge against Soviet abrogation of the ABM treaty, or should we scale down existing BMD programs and try for breakthroughs and a “grand solution”? Each choice had policy implications. But since the technology and policy team reports would be integrated only upon their completion, the task of technology evaluation and planning had to begin while the policy teams were still working to define the problem itself.

From the outset, the technologies study team emphasized a long-term program to research and develop a multi-tiered defense that would provide significant damage limitation. (The study team realized that a credible defense would have to have a low leakage of warheads, but no actual leakage number was defined.) It was also recognized that any U.S. R&D program to provide new options for defense would be met by a significant Soviet response, and the

postulated countermeasures played a pivotal role in defining the R&D effort.

Since the technologies study team consisted of people active, or with past experience, in the BMD field, few members lacked strong convictions on the subject. Some were advocates and others detractors, but all shared a great deal of intellectual skepticism and a willingness to voice their opinions. The strong bastion of doubters resided in the countermeasures panel. They were duty-bound to suggest a myriad of possible methods to defeat any defense. The real issue was the relative costs of measures and countermeasures (the cost-exchange ratio), and here, more unknowns were uncovered than definitive answers. In the end, there was inadequate opportunity to complete a thorough measure/countermeasure/counter-countermeasure analysis, but the countermeasures panel was particularly successful in forcing the other panels to rethink and reshape their technology proposals.

The stronghold of “true believers” came from the established BMD community. They were convinced that rocket-propelled, homing, hit-to-kill vehicles could in a short time prove effective in hardpoint defense while requiring the lowest investment (see the essay in this collection by Maj. Gen. John Toomay). Such an approach, they felt, would also satisfy the need for a terminal phase of a multi-tiered defense, though it would have little effectiveness in area defense without the other tiers.

The bastion of technological optimists could be found in the directed energy (speed of light) weapons advocates, who had great faith in the ability of science and technology to make tremendous gains, given enough smart people, capable management, and sufficient funding. Because of the short time period in which missiles can be intercepted during boost-phase, speed-of-light weapons (or possibly very high velocity projectiles) were considered essential.

The approach adopted by the technologies team emphasized high payoff, long-range capabilities rather than systems that might be more easily realized but might, in turn, be easily countered by offensive technologies. We decided to sketch out a five-year research program that would thoroughly explore the limits of technology on both the offensive and defensive sides, in order to winnow out the least promising defense options and acquire sufficient knowledge so

that a decision could be made in the early 1990s on whether to proceed with engineering prototypes.

The tasks faced by any strategic missile defense are formidable. To understand the defense concepts and technologies that are being investigated, it is useful to think of the flight of a ballistic missile as passing through four phases—boost, post-boost, mid-course, and terminal—each offering different opportunities and challenges to a defense system. A highly effective defense against a massive missile attack would require multiple tiers of defense, countering the offense at each phase until the fraction of warheads remaining is too small to be of military utility. (See figure on page 59.)

During the *boost phase* of a missile's flight, the advantage to the defense is that the flame from the booster's rocket motors provides a very bright marker that can be readily detected by space-based sensors and serve as an aim point for the defense's weapon. Moreover, a single successful intercept would destroy all of the warheads and decoys carried by the missile, yielding great leverage for the defense and reducing the task of subsequent layers of defenses. The challenge is that the boost-phase is a very brief time in which to intercept thousands of missiles—about 150–300 seconds for current ICBMs, 150–200 seconds for current SLBMs. Knowing this, the offense may time its attack to overwhelm the defense, or the offense may redesign and deploy entirely new missiles to reduce the duration of their boost-phase or harden them against damage by the defense.

During the *post-boost phase*, when perhaps ten or more warheads and hundreds of decoys are released from a maneuvering post-boost vehicle, or “bus,” the defense may still have some advantage if it can intercept the bus before it releases all of its warheads and decoys. The challenge is that the bus' maneuvering engines are much smaller and more difficult to detect than booster motors, and the offense may redesign its post-boost vehicles to shorten the maneuvering phase or to mask the engines and the deployment of warheads and decoys from the defense.

During the *mid-course phase*, the advantages to the defense are the long time available to locate and destroy targets (roughly 10–15 minutes for ICBMs, 7–10 minutes for SLBMs), the opportunity to bring both space-based and ground-based interceptors to bear, and the chance to destroy warheads far away from soft targets such as cities. The challenge to the defense is the sheer number of warheads

and decoys that may have been released—in the worst case, tens of thousands of warheads and hundreds of thousands of decoys. The offense can try to complicate the task by deploying not only clever decoys, but warheads inside of decoys, and so on. The defense must either discriminate warheads from decoys or make interceptions so cheap and easy that it can attack them all.

During the *terminal phase* between the warhead's reentry and its detonation over the target, the advantage to the defense is that the atmosphere will have sifted out most or all of the decoys, and the defense has the option of preferentially intercepting only those warheads that are still heading toward important targets on the ground. The challenge is that very little time is available, perhaps 30 to 40 seconds, to carry out the interception, and warheads that are "salvaged fused" (fused to detonate when intercepted) may still damage or destroy soft targets such as cities and would certainly complicate the problem of tracking those warheads not detonated.

The offense might try to defeat the defense in a variety of ways. Since there are many responses that can be postulated, and since an "unlimited" expenditure on offense can certainly defeat a "limited" defense, the real issue is to define the cost-exchange ratio between defenses and countermeasures, and to estimate how rapidly the adversary might deploy such countermeasures. These factors also have bearing on any arms-control agreements to limit offensive forces. To provide incentive for offense reduction agreements, the defensive technology response must enjoy a clear advantage in any cost-exchange analysis. To put it another way, if ten dollars of defense can be promptly countered by one ruble of offense, then we had better not invest our money. On the other hand, a favorable cost exchange would compel the Soviets to invest in defense and to seek offensive arms reduction in their own self-interest.

At each defensive tier, the defense must carry out four essential functions. One of these involves a combination of surveillance, acquisition, discrimination, and kill assessment. The second consists of pointing and tracking of defense weapons, the third, of interception and destruction, and the fourth, of battle management. All these functions must be integrated into an overall defense system. The concepts and technologies being investigated or identified by the Defensive Technologies Study Team as promising are summarized in table 1, opposite.

FUNCTIONS	BOOST	POST-BOOST	MID-COURSE	TERMINAL
DETECTION, ACQUISITION, DISCRIMINATION, KILL ASSESSMENT	SPACE-BASED INFRARED SENSORS	SPACE-BASED ULTRAVIOLET, VISUAL OR RADAR IMAGING SENSORS		AIRBORNE INFRARED OR RADAR SENSORS
POINTING, TRACKING	SPACE-BASED LASERS AND VISUAL IMAGING SENSORS			INFRARED TERMINAL HOMING
INTERCEPTION, DESTRUCTION	DIRECTED ENERGY WEAPONS, KINETIC ENERGY PROJECTILES			NON-NUCLEAR SURFACE-TO-AIR MISSILES
BATTLE MANAGEMENT	VERY HIGH SPEED INTEGRATED CIRCUIT HARDENED VS. RADIATION, NEW SOFTWARE DEVELOPMENT TOOLS			

Table 1 Elements of a Multilayered BMD System

Our present technological capabilities in each of the categories shown in table 1 are very far from what is needed for a robust defense against plausible Soviet threats and countermeasures in the future. Some of these shortcomings the study team regarded as critical; unless they could be overcome, we could not be certain that a robust defense could be achieved. We therefore proposed a long-term research program to determine whether the advances necessary in these critical technologies are feasible. These vital areas include the following:

SURVEILLANCE, ACQUISITION, DISCRIMINATION, AND KILL ASSESSMENT

At each phase in the missile's flight, the attacker may try to confuse and overwhelm the defense by increasing the number of warheads and by deploying decoys. Indeed, in setting out performance benchmarks for a defense system, we assumed that the Soviets might increase their offensive forces at a concerted rate so that their arsenal of strategic nuclear warheads might grow to two or three times its present size. The defense therefore must be able to detect and track tens of thousands of objects in flight, while rapidly and reliably distinguishing genuine targets from clever decoys.

Acquisition and discrimination during the boost phase will be greatly aided by the hot flame from the booster's engines; detecting colder warheads and decoys against the cold background of space

and discriminating between them during post-boost and mid-course phases may be possible by using a variety of sensors—optical, infrared, and radar; space-based, airborne, and ground-based—and integrating the information derived from all of them. Decoys may perhaps be readily distinguished from warheads if we can observe the “birth” of decoys at the very instant they are deployed, keeping track thereafter of which objects are warheads to be intercepted, and which are debris or decoys to be ignored—so-called “birth-to-death tracking.” All this will depend on important advances in sensor technology and the computer software necessary to process the volumes of data generated, as well as on careful studies of the characteristic signatures of warheads and decoys.

INTERCEPTION AND DESTRUCTION

The ability of any defense to respond effectively to an unconstrained Soviet threat is strongly dependent on the feasibility of boost-phase and post-boost interception. Two types of weapons are being considered for this task: directed energy weapons (speed-of-light weapons) and kinetic energy weapons.

Directed energy weapons could include space-based lasers, ground-based lasers, space-based particle beams, and X-ray lasers powered by nuclear explosives. The current goal is to construct laboratory-scale beam generators by the late 1980s or early 1990s and to demonstrate the feasibility of scaling them up to weapons-level performance by the early 1990s.

The critical parameter for beam weapons is beam brightness, the rate at which the weapon deposits energy on each square centimeter of the target. Brightness is an important determinant of the weapon’s range and of how long it must dwell on each target; it determines the number of weapons needed in orbit to cover Soviet missile launching areas. Beams of great brightness may become available from short-wavelength lasers such as the electrically powered excimer and free-electron lasers, but both of these are in relatively early stages of development. The free-electron laser might be quite efficient and could be a good candidate for eventual deployment in space, given successful resolution of several physics and engineering issues. Technologically much simpler than the electrically driven lasers would be the invention of an entirely new, short-wavelength chemical laser

exploiting recent chemical laser technology; an invention of this nature could revolutionize laser weapons. The search for just such innovative approaches was characteristic of the recommendations of the technologies study team.

Neutral particle beams would draw on a well-established technology base in the field of physics research accelerators. Such beam weapons would have the advantage of being difficult to shield against because of the penetrating power of atoms accelerated to nearly the speed of light. The sophisticated electronics of a missile or warhead might be disrupted or damaged by even low beam currents. The critical issue may not, in fact, be reaching the necessary level of brightness; instead, such problems as verifying kills, providing the power supply, and evaluating possible countermeasures may dominate the investigation of this promising approach. Neutral particle beams, for instance, become rapidly degraded and deflected once they enter even the thin atmosphere 100 kilometers above the earth, so development by the Soviets of a fast-burn booster that completes its boost phase within the atmosphere would defeat boost-phase particle-beam intercept. Replacing their arsenal of slow-burning liquid-fuel ICBMs with fast-burn boosters would be costly and time-consuming for the Soviets, and might well force them to reduce warheads. Nevertheless, the relative trade-offs in cost, effectiveness, and deployment time of entirely new Soviet boosters may be a critical issue for neutral particle beams.

Directed energy weapons powered by nuclear explosives are being investigated because they offer the prospect of supplying enormous quantities of energy in a short burst and at low cost. Concepts such as the X-ray laser are being examined to determine their feasibility. At the same time, the critical issues of how and where such weapons would be based are being studied, as well as the implications of possible Soviet use of such weapons to attack U.S. space-based defenses.

Kinetic energy weapons are the other devices being investigated for boost-phase intercept. These include so-called hypervelocity or electromagnetic launchers as well as more conventional chemical-fuel rockets, both of which would propel homing projectiles toward Soviet boosters at speeds of up to 10 kilometers per second. Based on orbiting platforms, such devices could also serve in mid-course interceptions and in defending space-based equipment from direct

attack. The goal would be to design weapons that are not only effective but also very inexpensive so that if sensor technologies cannot reliably discriminate warheads from decoys, the defense could afford to engage them all.

There is little question about the lethality of, for instance, an 8-kilogram projectile hitting a target at 10 km/sec (the approximate force of 100 kilograms of high explosive). But the development of a low-mass guidance and control system for such a homing projectile—one that is able to survive the initial acceleration—as well as low-cost chemical rockets or a space-based power supply able to deliver hundreds of megawatts of electricity for electromagnetic guns, may be the most difficult tasks of all.

BATTLE MANAGEMENT

Integrating multiple layers of defensive weapons into a highly reliable and fault-tolerant system will require high-performance computers, computer software, and adaptable communications networks far beyond present capabilities. The system must keep track of tens of thousands of objects, from birth to death, and allocate defense weapons in the most efficient manner. A network of space-based computers, capable of performing millions of operations per second, surviving virtually maintenance-free for years in deep space, and able to adapt gracefully to failures within the network, is just one of the challenges facing a multi-tiered defense system.

The software requirements are awesome as well. Millions of lines of computer instructions must be written and then tested in an exhaustive way to ensure that they are error-free. Both tasks may themselves have to be performed by computer, requiring in turn the development of computer-controlled computer programming and debugging. The difficulties posed by this aspect of the defense program cannot be overemphasized, nor should the revolutionary nature of developments in this field be overlooked.

SURVIVABILITY

The strength of any defensive system rests on its ability to survive a direct attack, and to continue to function effectively even if degraded

by attack. Space-based components that must orbit directly over the Soviet Union will face a host of possible threats, including direct-ascent ASAT weapons, ground- or space-based lasers, space mines, particle-beam weapons, and the effects of nuclear explosions. The tactics of survivability are familiar ones—hardening, active self-defense, concealment, proliferation, maneuvering—but applying them in a cost-effective way to future defenses will be a difficult challenge, one that may be pivotal to the outcome of the entire endeavor.

By no means does this short list of critical challenges exhaust the range of matters that must and will be addressed in the research and development program recommended by the study team. A whole set of support programs, for instance, must be pursued: determination of generic means for hardening boosters and the lethal effects of various weapons against those means (since we are not likely to get specific engineering design data on Soviet boosters); development of multi-megawatt space-based electrical power supplies, nuclear and non-nuclear, for weapons, sensors, computers, and so on; development of heavy-lift space launchers capable of carrying perhaps a hundred tons or more to orbit, rather than the space shuttle's current capability of twenty to thirty tons; and so on.

Those of us on the Defensive Technologies Study Team fully understood that present capabilities in all of the categories discussed above are very far from those needed for a robust defense against plausible responsive Soviet threats. As the research program evolves, however, new discoveries are likely to be made that may radically change the emphasis of the defense program. It is thus vital to stimulate, encourage, and fully investigate innovative approaches as early as possible in the program. These new ideas might arise from totally new sectors of the scientific and technical community, sectors that may not even be aware at the moment of the technical challenges we now face. To stimulate the broadest involvement of technical talent from government, industry, and universities, the Departments of Defense and Energy will provide funds to encourage the investigation of radically different concepts that offer enhanced capabilities, although bearing the admittedly higher risks associated with unexplored approaches. And since our discoveries might aid the offensive side as well, they could force us to eliminate particular

defensive approaches along the way. Because we need to eliminate all unfeasible or impractical defenses as soon as possible in order to focus our efforts, it is essential to approach the overall program with a healthy skepticism, as well as with the creativity associated with the exploration of a new field.

The report of the Fletcher panel was submitted to the Department of Defense in October 1983. In March 1984, the secretary of defense announced the establishment of a new special program, the Strategic Defense Initiative, that was charged with developing and carrying out an expanded R&D program on strategic defense, incorporating numerous ongoing defense activities with new ones proposed in the study report. Lt. Gen. James Abrahamson was appointed director of the program.

The first phase of the SDI, from now until the early 1990s, will consist of research. During this period, decisions will be made on whether to begin engineering development of specific weapons. The second phase will focus on systems development, when prototypes of actual defense components will be designed, built, and tested (assuming a decision is made to go ahead with defenses). The third will be a transition phase, with incremental, sequential deployment of defenses, presumably by both the United States and the Soviet Union. At this stage, significant reductions in offensive missile forces would hopefully be negotiated. The final phase would be reached when defense deployments are complete, and offensive missile forces at their negotiated low point.⁸

The Defensive Technologies Study Team prepared a fairly detailed plan only for the first—research—phase. To permit a decision by the early 1990s on whether to advance to the next phase, the Reagan administration requested \$1.99 billion in funding for the SDI in fiscal year 1985. \$1.78 billion was to go to Defense Department programs, with \$210 million earmarked for Department of Energy R&D on nuclear directed energy weapons. This was roughly 70 percent more than the 1984 request, although almost all the increase had been requested before the president's March 23 speech. (It is ironic that the amount actually appropriated for the SDI in fiscal year 1985 was \$1.4 billion, an amount *less* than was initially requested for BMD programs before March 1983.) The total projected budget for the first five years of the SDI is \$26 billion. The research phase could conceivably be completed as early as 1990, if one postulates a pace

limited only by technological advances; or later if the program is slowed down because of fiscal restrictions. No attempt was made by our study to estimate the costs for the second phase of the program, but certainly that estimate would play an important role in the decision whether or not to proceed.

Assuming that the SDI is pursued, where might we hope to be in the early 1990s? The technologies study team was fundamentally optimistic in light of the spectacular advances that have taken place over the last two decades in the technologies of sensors, computing and software, and defensive weapons. We did not find any fundamental reason why such advances should not continue in many areas. In view of the richness of available options open to us, there was a general belief that even if certain approaches had to be eliminated, the overall defense requirements could be met.

As I discussed earlier, a defense system must not only work, it must maintain its effectiveness, at a favorable cost-exchange ratio, against an opponent who attempts to defeat it. Some critics have asserted a priori that the defense will always lose to the offense in such competition. We believe that mastering technical challenges such as mid-course discrimination, low-cost interceptors, and high-brightness beam weapons will enable us to negate simple counter-measures and force the Soviets to resort to very expensive offensive responses.

The policy studies done by the other study teams have provided additional insight into the possible outcome of the SDI program. They remind us that the decision to deploy widespread ballistic missile defenses does not rest with the United States alone. Given their history, doctrine, and military programs, the Soviet Union might be the first country to seize the defense initiative. If we were to lack adequate knowledge of advanced defensive technologies at the time, the situation we would face would be grave. On the other hand, the development of effective defensive measures on *both* sides might serve to reduce offensive investments and increase our leverage in seeking mutual offensive arms reductions. As George Keyworth, the president's science adviser, stated: "We see the investigation of strategic defense options as an absolutely vital catalyst to real arms control."⁹

We are therefore entering the research phase with a realization that such policy considerations will have to play an important role if this

initiative is to succeed. The decision to implement effective defenses will depend not simply on technology, but will be the result of a complex combination of technology and policy. In this sense, the SDI cannot be likened to the Apollo program, the goal of which was well defined and not subject to change. Explaining this complex program and gaining support from the American people will present a significant challenge to its supporters. The key issue may be whether people will be willing for their government to embark on and commit itself to an admittedly ambitious program that cannot promise a guaranteed return on investment. In the final analysis, the decision may hinge on whether there is any alternative to the SDI as a means of assuring the nation's security.

By the time it had completed the reviews, planning, and report preparation, the Defensive Technologies Study Team still did not have a clear statement of its conclusion. The group therefore made a concerted effort to arrive at a consensus statement that could be presented to the president. It is appropriate here to quote the main conclusion that was finally approved by the DTST study:

By taking an optimistic view of newly emerging technologies, we concluded that a robust BMD system can be made to work eventually. The ultimate effectiveness, complexity, and degree of technical risk in this system will depend not only on technology itself, but also on the extent to which the Soviet Union either agrees to mutual defense arrangements and offense limitations, or embarks on new strategic directions in response to our initiative. The outcome of this initiation of an evolutionary shift in our strategic direction will hinge on as yet unresolved policy as well as technical issues.¹⁰

The paths our two nations will take in the pursuit of self-interest as well as common concerns will be influenced by technological changes, policy formulation, and strategic-arms negotiations. The consensus expressed in the DTST conclusions reflects a belief that even though no definitive prediction of the outcome can be made, the United States must begin a process that might offer a new direction and a new hope. Short-term, narrowly defined program elements were generally deemphasized by the DTST in favor of long-term issues that were poorly understood, but which we felt offered a greater prospect of achieving an effective defense. Our recommenda-

tions antagonized those who desired a short-term solution and gave sustenance to those who believed there would never be a credible defense. They satisfied those members of the study team who believed that defining the limits to technology provided a hedge against possible future Soviet developments; they also pleased those who felt that defensive R&D might limit the offensive arms race by introducing doubt in Soviet planners about the value of particular offensive weapons.

The views arrived at by the policy study teams were somewhat different. While their major focus, like that of the technology team, was on the potential of a full, multi-tiered defense system, they emphasized that defensive developments of much lower capability than the full multi-tiered deployment could be of value in strengthening deterrence. They were also concerned about maintaining public support throughout a long-term program, and were interested in examining interim capabilities that would be of real value. A logical compromise between our two perspectives would be to move forward aggressively with investigation and demonstration of the more mature chemical rocket technologies for the terminal and mid-course layers of multi-tiered defenses, while pursuing a long-term research program on other aspects of the program with emphasis on evaluating existing concepts and searching for breakthroughs in high-leverage boost-phase defenses.

It is my opinion that, although the policy and technology studies were individually valuable, their conclusions were never fully integrated. Those opposed to the SDI have seized on this deficiency in an attempt to defeat the entire project. In retrospect, it might have been more useful to try to integrate the teams at the outset. Yet, this would not have guaranteed success, and might, in fact, have introduced more confusion into an already difficult task. It might also have deflected the study teams from concentrating on their respective goals. Indeed, the problem of integrating human behavior and political institutions with rapidly evolving technology may prove to be the most difficult and crucial challenge to humanity's long-term survival. The teams' failure to resolve fully all the issues raised in this paper should come as no surprise: they will have to be debated with knowledge and impartiality for years to come. Indeed, one of the main values of the president's Strategic Defense Initiative may have been to call attention to the dilemma facing us, and to inspire us to

make use of our technical talents in innovative ways. We must not make decisions on the basis of preconceived notions or, still worse, prejudice, but must do so on the basis of knowledge of the facts and an understanding of their broad implications. The purpose of the Strategic Defense Initiative is to provide the hard data as well as the in-depth insight to allow truly informed decisions.

ENDNOTES

¹M.A. Wallop, "Opportunities and Imperatives of Ballistic Missile Defense," *Strategic Review*, Fall 1979, pp. 13-21.

²M.A. Wallop, "Letter to the Senate," July 8, 1983, unpublished.

³Daniel O. Graham, *The Non-Nuclear Defense of Cities: The High Frontier Space-Based Defense Against ICBM Attack* (Cambridge, Mass.: Abt Books, 1983).

⁴Edward Teller, private letter to the president, July 23, 1983.

⁵U.S. Department of Defense, *Soviet Military Power* 1984, pp. 34 and 36.

⁶Sayre Stevens, "The Soviet BMD Program" in A. Carter and D. Schwartz, eds., *Ballistic Missile Defense* (Washington, D.C.: Brookings Institution, 1984), p. 215.

⁷Two other contributors to this volume were involved in the study: Maj. Gen. John Toomay and Alexander Flax were deputies to James Fletcher (Alexander Flax was also chairman of the Soviet Countermeasures and Tactics Panel), and I was chairman of the Directed Energy Weapons Panel. The other panels were Battle Management and Data Processing; Surveillance, Acquisition, and Tracking; Weapons—Interceptors, Guns, and Other; and Systems Concepts.

⁸Lt. Gen. James Abrahamson, "The President's Strategic Defense Initiative," testimony before the Subcommittee on Defense Appropriations of the Senate Appropriations Committee, May 15, 1984.

⁹George A. Keyworth, "The President's Strategic Defense Initiative," testimony before the Committee on Foreign Relations, U.S. Senate, April 25, 1984.

¹⁰James C. Fletcher, "The Strategic Defense Initiative," testimony before the Subcommittee on R&D of the Committee on Armed Services, House of Representatives, March 1, 1984.

Assessing the President's Vision: the Fletcher, Miller, and Hoffman Panels

IT WAS A VERY APPEALING VISION that President Reagan invited the public to share in his March 23 speech—"a vision of the future which offers hope," a world free of nuclear dread, where nuclear weapons will be rendered "impotent and obsolete."

The president chose a surprising way to present his vision. In the closing moments of a televised speech arguing for a larger military budget, Reagan abruptly changed topics and announced what was no less than a revolution in American strategic doctrine. At the heart of his vision was a repudiation of deterrence—the bedrock of American strategic nuclear policy for three decades. "I've become more and more deeply convinced," the president remarked,

that the human spirit must be capable of rising above dealing with other nations and human beings by threatening their existence. . . . If the Soviet Union will join with us in our effort to achieve major arms reductions, we will have succeeded in stabilizing the nuclear balance. Nevertheless, it will still be necessary to rely on the specter of retaliation, on mutual threat. And that's a sad commentary on the human condition. Wouldn't it be better to save lives than to avenge them?

This was not just presidential whimsy. Three years before, when Reagan was stumping in the presidential primaries, he had spoken with the same profound concern and disappointment that our security rested on mutual threats, and with the same diffuse confidence that American technological strength offered an escape.¹ Nor did it seem to be just political posturing, for domestic or foreign

consumption. Reagan has shown rare animation and commitment whenever he discusses his proposal—the marks of a true believer.

It was perhaps this enthusiasm that prompted the president to rush ahead and present his vision to the nation before its implications had been fully considered. He had drafted the closing paragraphs of the speech himself, only five days before it was televised, and they were seen by only a handful of advisers.² It was not until ten weeks after the speech that he appointed three panels of experts to assess the feasibility of achieving the goal he had already set out. By October, the three panels had submitted their reports. By January 1984, the administration was fashioning a concrete defense program. In March, Secretary of Defense Weinberger released declassified summaries of two of these panel studies, along with his own overall report. He concluded that “a robust BMD system can be made to work eventually,” and sketched out a five-year research program dubbed the Strategic Defense Initiative (SDI).³

None of these reports is the stuff of popular reading. The prose is strictly utilitarian, the jargon impenetrable; the general reader would need a glossary to make sense of the glossary. Even a casual reader would notice right away, however, that much of the prose in Weinberger’s report was copied directly from the panel summaries, fostering an impression of broad agreement between the president’s vision, the advisers’ evaluations, and the Defense Department’s SDI program.

That impression would be wrong, for Reagan’s advisory panels in fact offered contradictory advice. The points of contradiction are vital, for they go to two assumptions at the heart of the president’s vision: that an escape from deterrence through retaliation is possible; and that the path of escape is technological, not political. In fundamental ways, the panels’ reports are less an endorsement of President Reagan’s vision than a reflection of a basic skepticism about its core assumptions.

THE FLETCHER REPORT

Devising a strategic defense so nearly leakproof that it makes *all* nuclear weapons “impotent and obsolete” means confronting not one challenge, but several—specifically, land- and submarine-launched ballistic missiles, bombers, and cruise missiles. And if parts

of our defenses are based in outer space, defending them against anti-satellite (ASAT) weapons poses an additional challenge.

President Reagan did not address all these challenges in his March 23 speech. The only weapons he mentioned specifically were strategic ballistic missiles; the only program he proposed was research and development on ballistic missile defenses (BMD). Days later, Secretary of Defense Weinberger asserted that the president's vision encompassed all nuclear weapons. Yet in June 1983, when the three study teams were appointed to assess the technological prospects and security implications of strategic defenses, their mandate focused only on ballistic missile defenses. When the SDI was announced in March 1984, it too addressed only ballistic missile defenses.⁴

Even working within this narrowed focus, the advisory panels came back with strikingly different evaluations of the path that ought to be followed. The Defensive Technologies Study Team (DTST; known as the Fletcher panel, after its chairman, James C. Fletcher) opened the body of its summary report with a rhetorical question: "What has happened to justify another evaluation of ballistic missile defense as a basis for a major change in strategy?" Perhaps the bluntest answer would have been that the president had already announced his commitment to comprehensive defense, and the panel had been told that, whatever its findings, it was not to embarrass the president. The answer provided in the panel report instead said that new technologies now offer the prospect of reaching out and intercepting ballistic missiles almost from the moment they are launched. To give at least some shape to the president's general goal of comprehensive missile defense as a focus for research, the Fletcher panel sketched out a hypothetical, multi-tiered defense system based on these prospective technologies, with each tier engaging missile warheads at a different phase of flight.

What security burden could such a system bear? Could it really liberate us from deterrence, as President Reagan hopes? On this, the report was politely evasive. "Meaningful levels of defense" might be feasible in the 1990s, it said, if we deployed terminal and mid-course layers of defense. Constructing an "effective defense," however, would be "strongly dependent" upon engaging thousands of Soviet missiles during their boost phase, before they could release thousands of warheads and perhaps hundreds of thousands of decoys. Boost-phase intercept requires stationing part of all of our missile defenses

in outer space, where they can get a clear shot at Soviet missiles in the first minutes of flight. For this task to be within reach, the panel report continued, a list of “critical technologies” would have to be tackled, “technologies whose feasibility would determine whether an effective defense is indeed possible.”

Three things are notable about this list. One is that deficiencies are to be found in every defensive tier. Even in mid-course and terminal BMD technologies, on which the United States has already lavished decades of effort and billions of dollars, current performance was judged by the panel as inadequate for a comprehensive missile defense. A second notable point is the panel’s estimate that R&D programs lasting ten to twenty years might be necessary before we are able to solve critical technological problems and begin deployments. Such time scales are very different from our past experience. In 1941, two years after crucial scientific work by Szilard and Fermi suggested an atomic bomb might be feasible, the Manhattan Project began its task with promise from the project advocates that a workable nuclear weapon could be ready within two years. It took four. In May 1961, President Kennedy committed the United States to landing men on the moon within nine years. It took eight. Ten-year system acquisition cycles for advanced weapons are not uncommon now, and the Defense Department has experience with them. A ten- to twenty-year development cycle for exotic SDI technologies, however, would be quite a novel case, and the Fletcher panel openly acknowledged the great uncertainties involved.⁵

Most notable was the panel’s silence on how effective it expected this “effective defense” to be. In touting the virtues of a multi-tiered defense, the report noted that if each layer in a three-tiered system allowed even 10 percent of its targets to leak through, the overall leakage rate for the whole defense system would be only 0.1 percent. But read carefully in context, this 99.9 percent effectiveness figure proves to be only an illustration, not a prediction. It has been reported that the panel’s classified report rejects its own illustration, and asserts instead that “it is not technically credible to provide a ballistic missile defense that is 99.9 percent leakproof.”⁶ In practice, whether each layer could handle the leakage from the previous tier would depend very much on the devices deployed and on how self-sufficient the layers were. If several layers relied on common components (for instance, common sensor satellites, a central com-

puter, or identical software programs), then they would not be genuinely independent tiers. A catastrophic failure of one tier or component might so overwhelm the next tiers that they too would fail just as catastrophically. The extent to which multiple tiers could raise the nation's confidence in defense performance, then, would depend upon technology and design choices that the Fletcher panel said could not be made for years or even decades.

While the Fletcher panel's summary report does not dwell on such problems, neither does it ignore or deny them. In its own muted fashion, the report is a rather candid document from experts who made every effort not to embarrass the president, and yet who knew from their own technical experience that they could not promise that his ultimate goal was within reach. The summary report hints of the conflicting pressures that existed on and within the panel. On the one hand, the tone of the closing paragraphs in the declassified version is upbeat, reportedly more upbeat than the panel's twelve supporting volumes of classified technical studies might warrant: "The members of the Defensive Technologies Study Team finished their work with a sense of optimism. The technological challenges of a strategic defense initiative are great but not insurmountable." On the other hand, when he presented the report to the Senate, panel chairman James Fletcher stated not that the panel *reached* an optimistic conclusion, but rather that "by *taking* an optimistic view . . . we concluded that a robust BMD system can be made to work eventually"⁷ (emphasis added). Moreover, the report speaks with cold candor of technological challenges that would give any reader pause. For instance:

Developing [computer] hardware will not be as difficult as developing appropriate software. Very large (order of 10 million lines of code) software that operates reliably, safely, and predictably will have to be deployed. *It must be maintenance-free for 10 years . . .*⁸ (emphasis added)

Even some of the panel's optimism is startling:

Analyses . . . suggest that a properly constructed shield [to protect space-based components] could provide effective armor against small kinetic energy weapons and most directed-energy threats. . . . Such a shield could reach 100 or more metric tons . . . For the quantities of material required, two other sources are feasible. Material from the lunar surface or from nearby asteroids can be brought to the vicinity of the Earth . . .⁹

Throughout, the report reiterates in a soft but firm voice that the technical feasibility of even one aspect of the president's vision—defense against ballistic missiles—is far from certain.

THE MILLER REPORT

The Fletcher panel was only one of three groups advising the president. The other two panels examined the policy import of new defense technologies for U.S. strategic objectives, and the effect this defense might have on our relationships with allies and the Soviets. Unfortunately, the report of one of these policy groups, an inter-agency group known as the Miller panel (after its chairman, Franklin C. Miller, director of Strategic Forces Policy in the Pentagon), has not been publicly released. Potentially, it could tell us the most about the future of the SDI, for even when done after a policy is announced, more as an analytic prop than a foundation for the policy, such interagency studies are revealing in the way they crystalize the distribution of opinion and influence within the bureaucracy. They have a subtle influence on public policy by indicating to all agencies where the meridian of opinion lies and by establishing a vocabulary of discourse. Time and again, as decisions must be made, the bureaucracy uses such studies as its compass and plagiarizes their phrases. The Fletcher and Hoffman panels, after all, were disbanded at the end of the summer, 1983; the members of the Miller panel returned to their desks within the bureaucracy, to begin implementing the president's strategic defense program.

THE HOFFMAN REPORT

The other policy group, the Future Security Strategy Study team (known as the Hoffman panel, after its chairman, Fred S. Hoffman), did issue a declassified summary of its study.

There are striking contrasts between the Hoffman and Fletcher reports. The first is simply the discrepancy in length. The Hoffman panel's unclassified summary is barely twelve pages long, almost identical, we are told, to the full classified version. If this indeed represents all that the panel felt need be said about the policy impact of President Reagan's proposal, it is a remarkably terse statement.

What is more striking about the Hoffman panel report is that after an exceedingly brief, even perfunctory, endorsement of Reagan's long-term goal of a nearly perfect defense, the report turns to quite a different concern: buttressing retaliatory deterrence by deploying "partial [missile defense] systems, or systems with more modest technical goals" as soon as this is feasible. Such an approach, the panel members argued, would offer "a hedge against the possibility that nearly leakproof defenses may take a very long time, or may prove to be unattainable in a practical sense against a Soviet effort to counter the defense."¹⁰

What the Hoffman panel proposed were progressive stages of defense deployments, starting most immediately with anti-tactical ballistic missile (ATBM) defenses for Europe, based upon available technologies for terminal defense. The next stage of defense buildup would come as soon as more advanced terminal and mid-course technologies were available; these defenses could be deployed to protect critical military targets in the United States. The third stage would be reached with the availability of exotic boost-phase defenses; these would be deployed to exert "leverage" on the Soviets, "even if they prove unable to meet fully sophisticated Soviet responses," that is, even if they fell short of the president's goal.

It is difficult to interpret the Hoffman report as anything but a skeptical dismissal of President Reagan's proposed comprehensive defense for the American people. The panel had little or nothing to say about what strategy and security might look like in a world of nearly perfect defenses. Their silence on this point was perhaps unavoidable, given their views of the Soviet Union's strategic goals and tactics. They described the Soviets' primary strategic objective as "domination of the Eurasian periphery"; the "preferred mode in exploiting their military power is to apply it to deter, influence, coerce—in short, to control—other states." Following this view to its logical extension, the panel concluded that the Soviets would make vigorous efforts to defeat any U.S. defenses.

But what of the new BMD technologies touted by the Fletcher study? The Hoffman panel could envision a high level of *technical* performance for a multi-tiered defense. After all, it noted, even if each layer intercepted no more than half its targets, a four-tiered defense could still be 94 percent effective overall. The problem was, "such a leakage rate is . . . sufficient to create catastrophic damage in an

attack of, say, 5000 reentry vehicles (RVs) aimed at cities. It would mean 300 RVs arriving at targets—sufficient to destroy a very large part of our urban structure and population.” (The Fletcher panel, of course, had assumed the future Soviet threat might reach 30,000 warheads, which could mean 300 RVs arriving at targets even with 99 percent defense effectiveness.) Clearly, one could be optimistic about exotic BMD technologies, yet pessimistic about a strategic revolution. As if anticipating that the United States would therefore never reach the ultimate goal of nearly perfect defense, the Hoffman panel’s report confined itself to being principally a brief for stabilizing retaliatory deterrence—rather different in scope from the president’s call for a security posture that “did not rest upon the threat of instant U.S. retaliation.”

The Hoffman panel’s proposals for partial defenses, deployed sooner rather than later, are considerably less ambitious than those of the Fletcher group, still less ambitious than the SDI. And yet at the same time, the panel served to broaden the rationale for the SDI by widening the issues beyond simply “Star Wars” technologies, beyond simply “nearly perfect” defenses. Many of the defense tasks proposed in its report do not depend on exotic space weapons, and its arguments for partial defenses are familiar from the ABM debates of the 1960s and 1970s. The debate has been resurrected, however, in a rather different context. Voices of alarm over the future stability of nuclear deterrence have been heard in the United States for more than a decade now, from both the Right and Left; the possibilities of exotic space-based technologies for defense have sparked public imagination; and President Reagan has recast public expectations with his own ambitious vision. In this current context, partial defenses of the sort proposed by the Hoffman panel may well find new life as an achievable compromise, technically and politically, between deploying no defenses and embracing fully Reagan’s ambitious and uncertain vision.

DETERRENCE AND THE PRESIDENT’S VISION

Defenses designed to buttress deterrence by protecting military command posts and retaliatory forces certainly sounds like a retreat from the president’s goal of living “secure in the knowledge that . . . security did not rest upon the threat of instant U.S. retaliation to deter

a Soviet attack.” But are they? The question really cannot be answered without a careful review of what security and strategy would look like in a world of perfect defenses—a review the Hoffman panel was supposed to present but did not.

In principle, deterrence and defense are opposite. Deterrence works to dissuade the Soviets from attacking us or our allies by threatening punishment in retaliation; it works on the Soviets’ intention and will. Defense, on the other hand, works by thwarting a Soviet attack when it occurs; it focuses on the Soviets’ ability to do us harm, rather than on their intentions.

If either deterrence or defense worked perfectly, would we need the other? A perfect defense would seem to make deterrence irrelevant, make us indifferent to the plans and actions of the Soviets; it would simply shield us from attack. Of course, if the Soviets were convinced they could not penetrate our defenses, they would presumably change their minds and not bother to attack. In this sense, a perfect defense would also “deter.” Nonetheless, perfect defense is *not* just another variety of deterrence. President Reagan formulated it correctly: defense saves by protecting, deterrence saves by threatening vengeance. In a world of perfect defenses, then, the United States would be liberating itself, as the president said, from the specter of retaliation, from mutual threat.

Or would it?

Even if a defense worked perfectly and stopped all incoming warheads, invoking the defense against an attack would use up valuable equipment and would leave us vulnerable to other attackers until our defenses were replenished. So we would still have an interest in dissuading others—by threat of retaliation—from taking “free shots” at us or from coercing us while our defenses were being restored. In addition, there might be occasions when we would wish to project force, rather than simply to defend ourselves. Offensive nuclear weapons are rather blunt instruments for diplomacy or military action, but they might prove necessary in protecting an ally from nuclear coercion in a distant place to which our own defenses did not extend perfectly.

Even in a world of perfect defenses, it appears, we could not give up offensive nuclear forces or retaliatory deterrence. And the further our defenses fell from perfection, the more our security would depend

on offensive forces, either for deterrence or for damage limitation through a preemptive attack on Soviet forces.

Yet another reason to keep offensive forces stems from the crucial role of boost-phase interception in any comprehensive defense system. Boost-phase intercept systems can work only if the defense weapons and their sensors are based in space or popped up into space at the moment of attack. Any space-based missile defense technology, however, will be very capable of destroying other objects in space—including other space-based defenses—long before it is ready for use as an effective BMD system. The side willing to shoot first with its BMD-turned-ASAT, and to follow up with an offensive strike, would have a great advantage—unless the other side maintained formidable retaliatory forces.

One way the United States could try to liberate itself from dependence on offensive nuclear forces would be to maintain a constant technological lead over the Soviet Union in offensive missile and BMD-turned-ASAT technologies. A diffuse confidence in the perpetual superiority of American technology is an important part of President Reagan's defense vision. Yet from a practical point of view, nothing so complex as a multi-tiered BMD network could be continually modernized. The initial investment in equipment would be too high to be scrapped wholesale with each real or feared breakthrough in Soviet technology. Modernization would have to proceed in cycles: the latest U.S. defense technology would be deployed; as it aged and Soviet technology advanced, incremental modifications would be made in our defenses to sustain a desired effectiveness level; when modifications could no longer keep pace, a major new U.S. system would have to be deployed. During these modernization cycles, the technological advantage would seesaw back and forth between the United States and the Soviet Union. The United States would have to fall back on threats of retaliation during those periods when confidence in our defenses was undercut.

In short, deterrence based on retaliatory weapons is a difficult condition to escape in a nuclear world. Even if the United States and the Soviet Union had comparable and near-perfect defenses and no other security interests beyond protecting themselves from each other, they would still have an incentive to keep offensive nuclear forces. If our defenses were less-than-perfect, giving up retaliatory forces would be foolhardy.¹¹

ARMS CONTROL AND THE SDI

What remains, then, of the president's vision?

A world in which deterrence still mattered might nevertheless become "defense-dominant," that is, a world in which (within limits) it was easier to be a defender than an attacker. We might arrive at this point by two paths. One would be through technological innovations that would make defenses cheaper than *both* offensive forces arrayed against them *and* weapons designed to attack the defense directly. Making comprehensive defenses cheaper than anti-defense weapons will be difficult, however, because of the paradox noted above: every development in boost-phase defense technology can be used by the opponent as an excellent *anti*-defense weapon.

The other path would be through arms control—mutual formal or informal agreement between the superpowers to limit offensive forces and anti-defense weapons, but not defenses. This brings us back to the Fletcher and Hoffman reports. Following its instructions, the Fletcher panel narrowed its focus to technical issues and returned with a vision of technological innovations that might give the defense significant leverage over the offense, "leading to the final, low-leakage system." And yet, recognizing that what our own technology gives us, Soviet technology can take away, the panel concluded that maintaining the defense's dominance over the offense could not be accomplished by technology alone. It would require arms control.

The ultimate effectiveness, complexity, and degree of technical risk in this system will depend not only on the technology itself, but also on the extent to which the Soviet Union either agrees to mutual defense arrangements and offensive limitations, or embarks on new strategic directions in response to our initiative.¹²

Advice like this had been heard before. One month after the first atomic bomb test in 1945, scientists with the Manhattan Project (Oppenheimer, Fermi, Compton, and Lawrence) offered a similar bit of counsel to Secretary of War Henry Stimson:

We believe that the safety of this nation—as opposed to its ability to inflict damage on an enemy power—cannot lie wholly or even primarily in its scientific and technical prowess. It can be based only on making future wars impossible. It is our unanimous . . . recommendation to you that . . . all steps be taken, all necessary international arrangements be made, to this one end.

The Fletcher panel did not probe Soviet motives, and so did not explain why the Soviets might be willing to resurrect arms control years after limits defined in the ABM treaty had been abolished to make way for missile defenses.

The Hoffman panel, on the other hand, squarely addressed Soviet motives but came away with little optimism for arms control, unless a wholesale transformation of Soviet character occurred:

Current Soviet policy on arms agreements is dominated by the Soviet Union's attempt to derive unilateral advantage from arms negotiations and agreements. . . . There is no evidence that Soviet emphasis on competitive advantage over mutual benefit will change in the near future, unless a fundamental change occurs in the Soviet Union's underlying foreign policy objectives.

If the new defense technologies offer sufficient leverage against the offense . . . the Soviets may accept a reduction in their long-range offensive threat against the West, which might be reflected in arms agreements. . . . Their current program emphases suggest that they would be more likely to respond with a continuing buildup in their long-range offensive forces.

In this panel's view, if anything could induce the Soviets to negotiate seriously (presumably, even after the demise of the ABM treaty), it would be a combination of Western toughness and technological dominance that threatened to thwart Soviet objectives. "In that event, it might also be possible to reach agreements restricting offensive forces so as to permit defensive systems to diminish the nuclear threat."

Where does this leave us? Members of the Fletcher panel argued that the United States could not assert and preserve defense dominance without arms control. The Hoffman panel doubted Soviet openness to arms control, unless the U.S. could assert technological dominance. Yet the defense secretary's report, released at the same time and ostensibly summarizing the advisers' findings, asserted that "defense against ballistic missiles offers . . . new opportunities and scope for arms control." This, of course, turned the Fletcher panel's conclusion on its head and transformed the Hoffman panel's pessimism into optimism, without providing any rebuttal of the panels' judgments.

The discrepancy in opinions between the Fletcher and Hoffman panels regarding arms control is not surprising, since members of the

Defense Department supervising the panels were reluctant to have them come in contact or coordinate their findings. Having two panels work separately on the same problem is an excellent way to get independent assessments. But here the panels were being asked to work in isolation on parts of a puzzle that were supposed to fit together. Precisely how the “policy” panels were to assess the political implications of strategic defenses, ignorant of the technologies and performance levels being recommended by the Fletcher panel—or how the DTST was to sketch out technology paths and requirements, ignorant of “policy” constraints—is not clear. In the end, staff members in Under Secretary of Defense Fred Ikle’s office (which supervised the Hoffman panel and, through Franklin Miller, the Miller panel) objected to the Fletcher panel’s remarks on arms control, on the grounds that this was a “policy” matter and not a technology issue. The deadline for submitting the reports arrived before the disagreement between the staffs of Ikle and DeLauer, and the discrepancy between the reports, were resolved.

CONCLUSION

The conflicting advice of the Hoffman and Fletcher panels, and their scaled-back visions of what the Strategic Defense Initiative might achieve, cut to the very heart of President Reagan’s vision. “Diminishing the nuclear threat”—in the Hoffman panel’s words—is a rather different vision from rendering nuclear weapons “impotent and obsolete.” Even granting that the very purpose of the SDI is to narrow the technical uncertainties about what can and cannot be achieved, there seems little doubt that both the SDI and the public debate over strategic defenses would have greater clarity if the fundamental issues raised by the Fletcher and Hoffman reports had been confronted, debated, and then integrated into our strategic defense policy. Surely, it matters to the public whether the risks and sacrifices entailed in pursuit of the president’s vision are likely to yield less-than-perfect rather than nearly perfect defenses, defenses of retaliatory forces rather than cities, a world free of mutual nuclear threats rather than one of buttressed deterrence. Yet long after the panels finished their work, these issues were still not placed in sharp focus. For instance, a White House pamphlet issued under President Reagan’s signature in January 1985 seemed to speak squarely on the

matter of whether we are pursuing a true defense—living “free in the knowledge that . . . security did not rest upon the threat of instant U.S. retaliation”—or merely buttressed deterrence:

U.S. policy has always been one of deterring aggression and will remain so even if a decision is made in the future to deploy defensive systems. The purpose of the SDI is to strengthen deterrence.

But the pamphlet also reiterated the president’s own phrase, “What if a free people could live secure in the knowledge . . .” as a banner across page one, and promptly blurred the meaning of “deter” on the same page by asserting “a very real possibility that future Presidents will be able to deter war by means other than threatening devastation to any aggressor—and by a means which threatens no one.”¹³

In a sense, the failure of the panels to bring sharper focus to the debate rests with the nature of the panels themselves. From the beginning, they were contending with a president who had already committed himself publicly to a goal of nearly perfect defenses. Although members of the panels clearly believed that more modest expectations were warranted, they had no reason on that point alone to confront Reagan and force him from his commitment. The panel members were in fact quite content with more modest goals than “perfect defense,” and thought that even modest goals justified a vigorous BMD research program. Moreover, either by design or good fortune, the defense system and research program sketched out by the Fletcher panel also seemed to discourage debate and hard decisions rather than to provoke them. Almost everyone’s favorite BMD technology or strategic purpose could find a place within the multi-tiered defense system.

If any of the panels were to provoke debate or dissuade the president from his commitment, logically it would be the Hoffman panel that would do it. Certainly the Hoffman group had a more coherent argument for its less-ambitious recommendations than did the Fletcher panel. But an argument is not an inducement, and in the way of inducements to confront choices or to change policies the Hoffman panel offered Reagan little or nothing. The Hoffman panel’s strident image of unrelenting Soviet competition was not necessary for a president already persuaded that the Soviets should be dealt with firmly; neither was it welcome to one also in a mood to offer Americans hope of a brighter future. And telling the president the

journey to a brighter future should begin with a request to the Europeans that they accept American ATBM missiles, was certainly no inducement.

From the president's standpoint, the hardest choice the Hoffman panel posed to him was whether to set aside the exotic technologies and his long-term vision of population defense—since escaping deterrence was doubtful—in favor of more prosaic technologies and near-term defense of retaliatory forces. But President Reagan was not about to make such a choice. The prevailing view in the White House was that the United States had been down that path already in the 1960s, and had stumbled on two problems: inadequate BMD technology, and domestic opposition to having BMD sites in the nation's neighborhoods. While new technologies might perhaps overcome previous deficiencies, the recent political obstacles encountered in finding a home for the MX missile showed that siting problems were, if anything, greater in the 1980s than in the 1960s. Moreover, since the U.S. could defend the bulk of its retaliatory forces only by scrapping or renegotiating current ABM treaty limits, and thus liberating the Soviets as well from ABM restraints, this made little sense if the only defenses at hand were prosaic, ground-based technologies that the Soviets, unfettered by domestic opposition, might exploit more readily than the United States. Space-based defenses could circumvent such problems, play to the American strong suit in exotic technology, and avert unpalatable choices between defense of retaliatory forces and defense of population. So long as the Hoffman panel was willing to say polite things on behalf of space-based technologies and the president's long-term vision, Reagan was under no compulsion to make hard choices. His vision could remain intact.

ENDNOTES

- ¹In interviews with a *Los Angeles Times* reporter in the spring of 1980, candidate Reagan remarked: "I think the thing that struck me here was the irony that here, with this great technology of ours, we can do all of this yet we cannot stop any of the weapons that are coming at us. I don't think there has been a time in history when there wasn't a defense against some kind of thrust, even back in the old-fashioned days when we had coast artillery that would stop invading ships if they came. . . . I do think that it is time to turn the expertise that we have in that field—I'm not one—but to turn it loose on what do we need in the line of defense

against their weaponry and defend our population, because we can't be sitting here." Quoted in Robert Scheer, *With Enough Shovels* (New York: Vintage Books, 1983), pp. 233-234.

²Robert Scheer, "Teller's Obsession Became Reality in 'Star Wars' Plan," *The Los Angeles Times*, July 10, 1983, section VI, pp. 6-9.

³Texts of the unclassified summary reports from the Defensive Technologies and Future Security Strategy study teams and from Secretary Weinberger can be found in "Strategic Defense and Anti-Satellite Weapons," U.S. Senate Hearings before the Committee on Foreign Relations, 98th Cong., 2nd sess., April 25, 1984, pp. 94-175. Page references to the reports below are to the publicly released versions, with corresponding page numbers in the Senate Hearings noted in brackets [].

The Defensive Technologies panel had some sixty members. Formally, it reported to Richard DeLauer, under secretary of defense for research and engineering; informally, the panel chairman, James Fletcher, discussed the group's progress directly with Secretary of Defense Weinberger. The Future Security panel had twelve members, plus a senior policy review group of an additional nine members, and it submitted its findings to Franklin C. Miller, director of strategic forces policy in the office of Fred Ikle, under secretary of defense for policy. Both panels were drawn from the national weapons-research laboratories, defense-related private industries and research firms, universities, and the military services. The panels' members and their affiliations are listed in the reports.

Although an unclassified version of the Miller panel's report has not been released, brief testimony by Franklin C. Miller on the panel's work may be found in the Defense Department Authorization for Appropriations FY1985, U.S. House of Representatives, Hearings before the Committee on Armed Services, 98th Cong., 2nd sess., part 6: "The Strategic Defense Initiative," March 8, 1984, pp. 2; 948-59.

⁴Studies of defenses against bombers and cruise missiles were also begun at this time within the Defense Department. But they were not part of, nor integrated into the conclusions of the Fletcher or Hoffman panels, nor are they part of the Strategic Defense Initiative.

⁵The SDI may also prove novel in its final cost. The Manhattan Project cost \$2 billion between 1941-1945 (about \$13 billion in 1984 dollars), roughly 0.2 percent of total GNP of those four years. The Apollo project cost \$25 billion between 1961-69 (about \$57 billion in 1984 dollars), roughly 0.4 percent of total GNP of those years.

The nation's GNP in 1984 was \$3664 billion. Assuming that a real growth rate (after inflation) of 3 percent is achieved for the next 20 years, total cumulative GNP over those years would be roughly \$98,500 billion. So, to equal the same portion of total GNP as the Manhattan Project, a comprehensive defense system would have to cost no more than \$200 billion; to equal Apollo, no more than \$400 billion. In contrast, a Defense Department study submitted to Congress in 1982 estimated that the cost of a space-based laser BMD system capable only of "damage denial" (that is, less-than-perfect defense of the population) would be \$500 billion. See Senate Foreign Relations Committee hearings, "Strategic Defense and Anti-Satellite Weapons," op. cit., p. 67.

⁶The Fletcher report, p. 10 [p. 151], and "U.S. Strategic Defense Options: Study Urges Exploiting of Technologies," *Aviation Week & Space Technology*, Oct. 24, 1983.

⁷See testimony by James C. Fletcher during the Hearings before the Committee on Armed Services, *op. cit.* (footnote 3), p. 2919. Fletcher was quoting from the classified version of the panel's summary report, and this passage was a summary judgment very carefully crafted so that all members of the panel could endorse it.

⁸The Fletcher report, p. 19 [p. 160].

⁹Quoted in *Aviation Week & Space Technology*, Oct. 17, 1983, p. 19, from the classified version of the Fletcher report.

¹⁰The unclassified version of Hoffman report may be found in the Senate Foreign Relations Committee Hearings, "Strategic Defense and Anti-Satellite Weapons," *op. cit.*, pp. 125-140.

¹¹Within days after the declassified versions of the Fletcher and Hoffman reports were released, Defense Department officials confirmed that they did not foresee a future in which the U.S. would be able to give up its offensive nuclear forces, even when defenses were deployed. According to Under Secretary of Defense Fred Ikle, the only way to escape our need for offensive nuclear weapons would be through a combination of defenses plus arms-control agreements. See the testimony of Ikle, Under Secretary of Defense Richard DeLauer, and director of Defense Advanced Research Projects Agency (DARPA), Robert Cooper, Hearings before the Senate Armed Services Committee, cited in footnote 7, p. 2924.

¹²James C. Fletcher, testimony, cited in footnote 7 above.

¹³"The President's Strategic Defense Initiative," pamphlet released by the White House, Jan. 1985, pp. 3 and 1.

Strategic Defense: A Systems Perspective

IN DISCUSSIONS ABOUT PRESIDENT REAGAN'S Strategic Defense Initiative, the popular tendency is to speak as if inventing new technical components, such as directed energy weapons, is the same thing as creating a ballistic missile defense system, and, furthermore, as if devising a missile defense system is the same thing as providing strategic security to the nation and our allies. The task is more complicated than that. The new defense *weapons* that have been receiving so much attention are to be but one part of a complex strategic *system*; planning wisely for strategic defense, then, requires taking a systems perspective.

Let us use a simple analogy: we can compare a systems perspective with the approach taken by a good architect, who begins by assessing the purpose a new building is to serve and then asks, "What kinds of materials and components, assembled in what sequence and manner, would best serve this purpose, given the building's environment?" In a similar way, the first step in planning a ballistic missile defense should be to assess our strategic purposes, including the role we expect nuclear deterrence to play in our security.

In assessing where and how missile defenses would fit in this overall posture, we should begin with the premise that a perfect defense against all nuclear threats is feasible neither technically nor economically, at least not in the foreseeable future. On this, there now seems to be general agreement throughout the defense community.¹ Consequently, since our security will continue to rest upon a combination of offensive and defensive forces, before we are in a

position to decide which kinds of ballistic missile defenses are desirable, we need to consider a variety of combinations and evaluate their impact on nuclear deterrence, the stability of international relationships, and our security priorities. Performance requirements must be defined broadly; obviously, the system must be able to intercept missiles, but it must also effectively perform such functions as command-and-control, self-defense, and operational maintenance and testing.

Once we have a system design in mind, we must investigate the best way of deploying such a defensive system, remembering that no complex system can be deployed quickly. We must therefore devise a pace and sequence of construction that does not leave us vulnerable during deployment. This brings us back to the problem of determining the proper mix of defensive and offensive forces, given limited resources.

The multilayered BMD system described by the administration's Defensive Technologies Study Team (the Fletcher panel) offers an example of the complexities we face. The figure on page 59 shows in schematic form the various layers of the system: the boost and post-boost phase where multiple warheads are released by the attacking ICBMs or SLBMs, the mid-course phase where large numbers of decoys may travel with the warheads, and the terminal phase where the warheads are a minute or less from their targets. The hypothetical BMD system that opposes the attack could contain many tens or even hundreds of terminal phase elements, tens to hundreds of warning and tracking satellites, and several hundreds to thousands of weapons-carrying satellites. The BMD system must have a self-defense capability, using both its own sensors and weapons and separate defense satellites for special threats. Ground-based elements of the system could include both the terminal defense elements shown and surveillance probes and weapons units that could be launched into space after warning of attack to make intercepts during the late mid-course phase.

Figure 1, opposite, shows the relationships among the various elements of such a BMD system and their connections to defense higher authorities, allied forces, and offensive forces. The shadow indentations in the diagram illustrate either backup elements or multiple space-based and ground-based elements. Each layer would

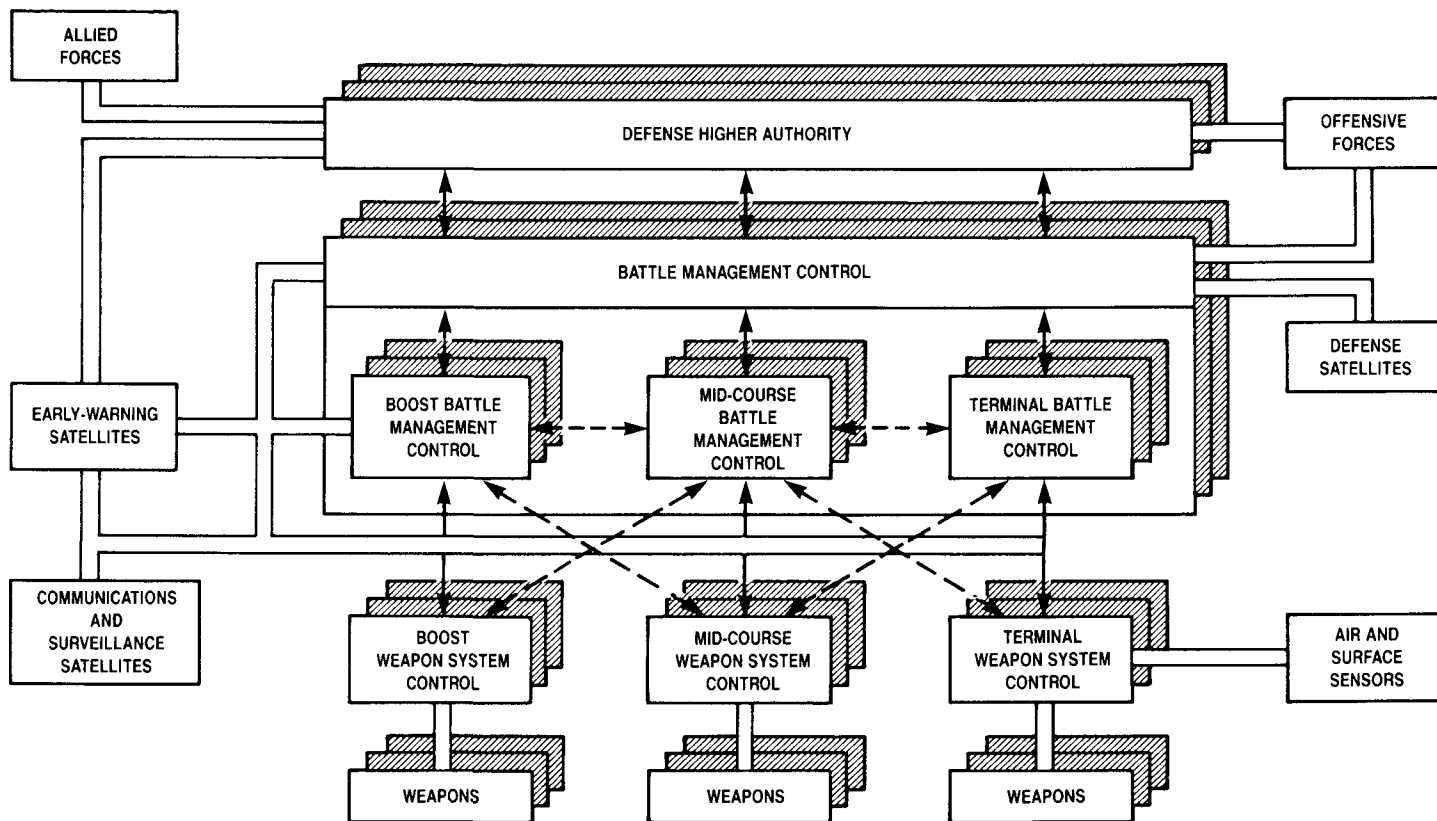


Fig. 1 Command-and-control of Multilayered BMD System

ideally be as self-sufficient as possible, and the layers would be integrated by multiple communications networks.

At the moment, the Strategic Defense Initiative is only at the research stage. The next hurdle will come at the component stage. Since the actual performance of components can differ by orders of magnitude from the ground-testing of devices, the challenge facing scientists is to close the inevitable gaps between design and development, and development and deployment. The final challenge will come at the systems stage, when we will not only have to bridge the gap between the performance of components individually and the performance of components in interaction with each other, but we will have to make sure the system can operate in a hostile environment of countermeasures and physical attack. These issues are critical for the final performance of the BMD system. Unless they are addressed at an early date, unanticipated problems may force substantial delays later on, if and when deployment is decided upon.

If we compare the multilayered missile defense systems with previous major defense programs, it is apparent that an unprecedented amount of time and resources would be needed to deploy a comprehensive BMD system. The effort would be significantly greater, for example, than our programs in the 1950s and 1960s to develop and deploy comprehensive air defenses, or our strategic offensive systems of the 1950s, 1960s, and 1970s. This new BMD effort would dominate military and space budgets and activities for decades. It would result in major changes in our military posture, in our other military activities, in our relations with our allies and the international community, and it would fundamentally alter public perceptions about national security.

Such a comprehensive BMD program can succeed in the United States only with broad public support. Public support, however, is contingent on finding solutions that are generally agreed upon, or are based on workable compromises. Timely research programs on the system capability aspects of strategic defense are therefore urgent, not only because they will be needed for informed decision-making, but also because they provide the foundation for public understanding of and support for these decisions.

THE STRATEGIC PURPOSES OF DEFENSE

We have noted that a systems perspective should begin with a definition of the purposes that strategic forces must serve. One difficulty in defining these purposes stems from the current controversy over strategic doctrine and the proper role of strategic defenses—particularly BMD—within that doctrine. For example, the report of the president's policy advisers (the Hoffman report) envisioned a mix of strategic defensive and offensive forces and emphasized the role of BMD in strengthening nuclear deterrence. The implication of the report is that nuclear deterrence based on the threat of retaliation or countervailing action will remain an essential element of our strategic doctrine, regardless of the offensive/defensive mix in the force structure.

A lively point of debate today is the extent to which deterrence depends on the capacity of our strategic forces and command system to survive a massive nuclear attack. There seems to be general agreement that improving the survivability of our offensive system is both desirable and feasible. But there is great debate over the desired character and size of our offensive forces, the extent to which protracted endurance is needed and feasible, and the variety of strike options to be kept open. This debate is complicated by disagreements over the contribution that arms control might make in bolstering deterrence.

The proposed deployment of a substantial BMD capability raises these issues again, but in the context of a much more complex strategic posture involving a mix of offensive and defensive systems. A BMD system could help offensive forces survive. However, the BMD system itself must be able to survive and work at least as long as the things it is designed to protect. If the Soviets increase and improve their offensive forces and deploy their own BMD and ASAT systems—and that is highly probable—this will further complicate the situation.

Uncertainty has its advantages, however: it would greatly complicate matters for a Soviet attacker, and some proponents of BMD (the Hoffman panel, for instance) believe that adding uncertainty is one way BMD can strengthen deterrence. But uncertainty also impedes

our ability to determine whether deterrence based on various offense/defense mixes is stronger and more stable than deterrence based only on offensive forces. We must consider that the ability to survive and to fight, implied by BMD, might well lower the nuclear threshold rather than strengthen deterrence.² For instance, in a complex world of BMD deployments on both sides, how confident will we be of our own capability to resist an attack and retaliate, and how might this weaken deterrence and our sense of security? Do we have some idea of what our operational doctrine would be in this more complex world, if deterrence should fail as a result of either a calculated or an irrational attack? Which elements of domestic and allied strength are to be given the highest priority if not all can be perfectly defended, and how cost-effective would less-than-perfect defenses be in these cases? Would BMD, especially if limited to defense of our retaliatory forces, reduce the utility of first-strike attacks against us and raise uncertainties enough to deter them; or would it have the opposite effect, raising the scale of possible limited nuclear attacks?

The acquisition and integration of new strategic defenses and offensive forces should, of course, be guided by some coherent strategy, which means we must try to grapple with these uncertainties. This will require the use of gaming, dynamic engagement models, or other methods to analyze the potential war outcomes when both sides deploy varying mixes of strategic offensive and defensive forces. Static cost-exchange ratios³ cannot be used to assess the cost-effectiveness of BMD systems unless the value and the number of the targets to be defended are considered, and the design and performance of the systems being analyzed are well known over a wide range of contingencies. Performances, however, will never be knowable in advance, in part because these systems cannot be tested realistically (we will return to this point later).

In sum, the range of uncertainties introduced by BMD may in fact result in *incalculable outcomes*, producing a different kind of deterrence for which our ideas and analyses thus far have not prepared us. Whatever its character, to be credible this deterrence will require a mix of both offensive and defensive forces with much more complex, diverse, survivable, enduring, and high-performance wartime capabilities in a nuclear environment than anything we now have in our strategic forces.

DEFENSE PRIORITIES

Because ballistic missiles are not the only nuclear threat we face, BMD systems alone will be insufficient for the full spectrum of strategic defense objectives. Unless and until defenses can be constructed to cope reliably with other threats—from aircraft and cruise missiles, for example—any strategic defense posture will be seriously vulnerable.

The current emphasis being given to BMD seems to imply that an attack by ICBMs is probably the most stressful defense situation we are likely to face. The reasoning appears to be that if this threat can be mastered through a multilayered defense, then meeting all other military threats will involve lesser challenges and smaller efforts. But this judgment is unproved, and perhaps unprovable. We must bear in mind that the future is certain to bring major technological advances in aircraft, cruise missiles, and space platforms used for communications, surveillance, and anti-satellite missions. On-station or alert times of such new offensive forces—both nuclear and conventional—may well be high, with proliferation greatly broadened and maneuverability and other performance measures greatly enhanced; their ability to avoid detection by electronic means such as radar may be greatly increased. All this is certain to heighten our concerns in other security areas such as the readiness and modernization of our own forces, the adequacy of our air defenses worldwide (including our naval task forces), the balance of conventional forces within NATO, the adequacy of our anti-submarine warfare forces, and so on.

Many new BMD technologies may themselves prove useful in certain of these other security areas, and this may permit us to avoid some hard choices and trade-offs. Conversely, the same BMD technologies, deployed by an adversary, could pose severe new threats in these other areas. For example, the use of lasers on the conventional battlefield or as anti-satellite weapons would create wholly new problems. Comprehensive planning that takes seriously these wider impacts of ballistic missile defense is needed to accompany the BMD research efforts that will provide empirical data for such assessments.

OFFENSE/DEFENSE INTERACTIONS

The operational relation between offenses and defenses is something a systems perspective must also consider. It is particularly important

in our planning to consider to what extent the operational performance of our BMD system in the midst of a nuclear attack will dictate in what way and how soon we plan to use our offensive forces.

In the strategic nuclear situation, the responses of defense and offense are tightly interrelated. This is illustrated by the following example: assume that both the United States and the Soviet Union have each deployed BMD systems whose performance in actual war situations is unknown. If our BMD turns out to be highly effective under attack, we might want to respond only lightly with our offensive forces. If our BMD is highly ineffective, however, delays in our response may well jeopardize the very forces we need to retaliate. And if the attacker has a BMD system that proves effective against our response, our resulting vulnerability may be even greater. Of course, we cannot know precisely how effective our defense is until an attack is underway, so we may need to formulate and execute our response at the instant of attack. Yet consistent with current U.S. policy, we must assume that a fully automated, offensive response would never be part of our operational plans.

From a conceptual point of view, this situation may appear to differ little from the one we currently have that relies on offensive forces alone. Yet, the absence of sure knowledge about the performance capability of *both* sides' BMD systems greatly complicates our task of developing appropriate offensive forces and responses to an attack. For example, right now we cannot know for certain how many of our ICBMs and SLBMs might survive a Soviet attack, but we do know that those that do survive will, with high probability, reach their targets; in a BMD world, even this would become uncertain, increasing the difficulty of our operational planning. At some point in the course of battle, our own forces may need to pass through our own defensive screens, and untested "rules of engagement" for our defenses that allow our own forces through, but not those of the attacker, will add another uncertainty.

DEPLOYING OUR DEFENSES

As we noted above, a complex defense network cannot be deployed quickly. The planning of any ballistic missile defense must consider the best methods of developing, deploying, and testing such a system in stages, through a transition period that may last for decades.

As the Soviet threat and the international political environment change, our defense systems may be perpetually in transition. Since a poor defense might actually undermine our security rather than minimally enhance it, we must be sure at every point in the transition that each defense component we have deployed functions well enough to promote stability in crises and military postures.

To achieve this end, we may need to take oblique paths towards our ideal system; in fact, planning the actual transition may be even more challenging than devising a detailed ideal system. For instance, once a multilayered BMD system is fully deployed, it is possible for the performance of each layer to be fairly modest yet the whole quite effective: four layers, each intercepting only 50 percent of its targets, could be more than 90 percent effective overall. Such modest performance levels for each layer are likely to be within easier technological reach and more cost-effective. But if the system as a whole becomes adequately effective only when *fully* deployed, should we wait and deploy the layers all at once, or deploy one at a time? If one at a time, will such low performance levels be acceptable and stable during the transition, or must the initial layers be made more effective (and more costly) than will eventually be needed? What changes in our strategic and operational doctrines will have to accompany the changing levels of effectiveness, and how must these be coordinated with changes in the configuration of our offensive forces? Where and when are defenses against other nuclear threats (air defenses, for instance) to be deployed so that we can always be assured of balanced protection and stability? Assuming the Soviets will try to shape their offenses to exploit transitional weaknesses in our defenses, how adaptable can or must our ideal system be during the transition period, to avert possible vulnerabilities?

The nature of nuclear deterrence and the stability of international political relationships are bound to change during the time that strategic defenses are being created and deployed. What is therefore needed is a far better, more rigorous understanding of the relationships between continually changing military postures and stability.

COMMAND-AND-CONTROL OF STRATEGIC DEFENSES

An effective strategic weapons system is one that constantly monitors and evaluates its own preparedness throughout periods of peace, so

that it can respond effectively in the event of war.⁴ The complexity of this task for a multilayered BMD system was stated by the Fletcher panel: the system must be prepared to “bring to bear several hundred space, airborne and surface assets to counter several tens of thousands of offensive threat objects in a period of about thirty minutes following the start of an offensive nuclear attack.” Moreover, it must do this in an environment in which anti-satellite weapons (such as laser and beam weapons), electronic jamming, space mines, and nuclear weapons (fired from surface-based missiles, for example) could be attacking the defense itself. Note that in a multilayered system, the initial defense against Soviet ICBMs would occur over *their* territory, where Soviet ground-based countermeasures could be concentrated.

To be ready for battle, the defense system must have fulfilled three conditions. It must have performed reliability testing and self-repair on perhaps hundreds of remote, unattended, and long-enduring space-based weapons stations; it must have established and enforced minimum keep-out zones in space for potentially lethal objects or countermeasures; and it must have tested in as realistic a manner as possible all of the system’s battle functions, including coordination with offensive forces and national command authorities, and its ability to sustain effectiveness when portions of the system are damaged or destroyed by hostile action. It must also assure weapons safety, arming, and release. If the whole system is deployed in stages over a period of decades, the command-and-control procedures must constantly be adapted and tested throughout the transition, to assure effectiveness and security. Yet command-and-control has never been practiced on such a scale, and has never had to contend with such complexity.

The challenges described above can be illustrated by a more detailed look at several crucial tasks the system must perform.

BIRTH-TO-DEATH TRACKING

Accurate discrimination and tracking of genuine warheads and rapid kill assessment are crucial to the efficient use of weapons by any defense. But engineering data on the targets’ characteristics may be uncertain or scarce; active countermeasures (such as electronic jamming and laser blinding of sensors) must be anticipated; targets and

decoys may not move on predictable ballistic trajectories; and two or more objects may be in the same discrimination cell of a surveillance sensor.

To cope with all this, the defense system will have to gather data from a great number of sensors and integrate it into a coherent picture. Surveillance sensors will require power levels and source/receiving structures at least one order of magnitude in performance and size beyond today's technological capability. Also, the speed, reliability, and intelligence that the data-processing components will require far exceeds the ability of today's computer hardware and software. This brings us to a second challenge.

SOFTWARE DESIGN AND DEVELOPMENT

The computer software of a complex defense system must be error-free and must operate reliably twenty-four hours a day in peace and war. Software throughout the system would also have to be designed, implemented, and tested years before operation. We would need new design and testing techniques to provide for correct operation under all feasible contingencies and at all component and system levels, as well as new techniques to modify and retest software remotely. The task of replacing or modifying software installed in computers on board satellites would require secure communication links possessing near absolute accuracy.

The tasks of managing the operational complexity of the BMD system and avoiding unforeseeable breakdowns would be handled by the computer software distributed throughout all the elements of the system. Software could thus become the limiting factor in the performance and reliability of BMD. Little is currently known about the potential size and complexity of the computer program codes that would make up the software for a multilayered BMD system. The Fletcher panel has estimated that the command-and-control software would be about 10 million lines of interrelated operational code, but this estimate was made at a time when a definitive system design did not exist.⁵

The nation's experience in developing and deploying software for large-scale, real-time control systems is limited. The SAGE air defense system begun in the 1950s, the National Air Space System for air traffic control built by the FAA in the 1960s and 1970s, and the

Safeguard anti-ballistic missile (ABM) system built by the Army in the late 1960s and early 1970s are notable examples.⁶ Each of these systems had about 500,000 interrelated operational lines of software code in their final computer programs. This does not include the support software that was needed for assembling, testing, and verifying the operational code. The support software, which was not as interrelated and complex as the operational code, comprised at least as many lines of code and sometimes much more.

Designing, developing, implementing, and testing each of these operational software systems took over one thousand man-years of effort by professional staff over periods of up to a decade. Almost twice as much effort was required to plan, design, test, and verify the design, and then specify for the software the detailed operational performance of each overall mission system (air defense, air traffic control, ABM) as to produce the operational software code itself. This is typical of the development of large-scale computer-based systems.⁷ And this does not even take into account the design and development of hardware.

If we make a linear extrapolation from our past experience, the overall effort needed to plan, design, and specify the performance of a comprehensive BMD system, and then to develop, implement, test, and verify the operational software code to meet these specifications would be several tens of thousands of man-years.⁸ Extrapolation may be misleading, however, as the air defense, air traffic control, and ABM systems developed in the 1960s and 1970s tracked only a few hundred objects and made only tens of intercepts at a time. Our postulated BMD system would have to track several tens of thousands of objects and direct hundreds to thousands of intercepts at a time. Furthermore, it would have to carry out these tasks while many complex, software-dependent interactions were taking place among the various layers of the defense system and with offensive and allied forces. It is possible that a team of a few thousand professionals working for up to twenty years might be needed to accomplish such a feat. This would be an undertaking unprecedented in the history of software development and implementation.

Techniques for developing and producing software that we can now project for the 1990s include automatic programming and artificial-intelligence support programs—computer programs that write and test computer programs. While these techniques may

ameliorate the task of writing software code, they will not simplify the tasks of designing the overall software program itself and confirming its reliability. If the interrelated operational lines of code needed for a BMD system could be reduced to less than 2 million or so, rather than the 10 to 20 million now estimated, we may with some confidence estimate that a reliable program of some 2 million lines of code might be produced in a reasonable time. Simplification could be achieved in a number of ways: by using common software packages in defense components such as satellites; by using approximate rather than optimal algorithms and rules for weapons allocation and intercept control; and by preassigning defense elements to known threat corridors. If these measures prove feasible and relatively efficient, then the complexity of the BMD system could be reduced significantly. Given the current uncertainties about the design of a BMD system, however, the feasibility of such a simplification effort is highly uncertain now.

Thus, our ability to build thoroughly reliable and high-performance command-and-control software could be the greatest challenge to achieving an effective BMD.

DEFENSE SYSTEM ACTIVATION AND SUSPENSION

Judicious control of weapons involves striking a balance between readiness for use and assurance that use occurs only when and as intended. Offensive nuclear weapons, of course, pose unique and serious questions in this regard. In the case of the non-nuclear defensive weapons as envisioned for the SDI, different questions arise. Space-based, unattended weapons would have to fire early enough to be effective during the boost phase of attacking missiles, a period lasting no more than tens or hundreds of seconds, lest the mid-course and terminal layers of the defensive system become saturated. Given the short response times available and the difficulty of reaching decisions within these times, we must confront the question of "automated response."

The need for a high degree of automation in the weapons release process of a boost-phase-intercept system was noted by the Fletcher panel in its studies. Many people within the defense community have considered such procedures and have concluded that fully automated responses by machines, with programs designed long before opera-

tion, would be acts of folly. In the case of a defense system made up of non-nuclear weapons, there is one mitigating factor—the consequences of a false start need not be catastrophic. However, given their experience with computers, the public and the politicians have shown little trust in assigning machines such decision-making roles. Expeditious responses in a combined defense/offense system would thus require what we have today in our nuclear weapons control procedures: a combination of human judgment, delegated responsibility and defined procedures, rapid execution capabilities, and rules of engagement suited to particular levels of crisis or threat and the amount of strategic warning-time available.

Another problem involving the control of weapons concerns the termination or suspension of a conflict. We would always hope that if deterrence fails, any conflict, especially one involving strategic nuclear forces, will be stopped as soon as possible. But a pause in battle may represent a true termination, or only a temporary suspension of hostilities. In either case, our ability to assess rapidly our defense system's status and performance, and to poise it to resume operations may be crucial to preserving the pause in hostilities. Thus, it would be necessary for our system design to include rapid stop/restart capabilities in both our defensive and offensive forces. The system-design implications of incorporating stop/restart features deserve study and research.

SYSTEM MAINTENANCE, TESTING, AND EXERCISING

Assuring that a highly automated BMD system works as intended, and maintaining it in peak condition for years, would constitute a new and unprecedented challenge. Innovative forms of acceptance testing and of routine exercising and operational testing would have to be devised for the overall system in order to assure thorough reliability and effectiveness. System-operational testing would be exceptionally difficult, given that many parts of the overall system could not be tested together operationally except under the hostile environmental conditions of an actual war. Since we would have to rely on simulation of war conditions to evaluate BMD system performance, and because such exercises can never be thoroughly realistic, the operational performance of the system under major attacks of varying kinds would be highly uncertain.

Maintenance of the operational system would also be difficult. Defense satellites, for instance, would be large, numerous, complex, expensive, and in some cases located as far away as tens of thousands of kilometers. Manned or robot repair and replacement of parts would be necessary. Systems research is essential to define maintenance and testing requirements and concepts, especially during the long periods of transition to full deployment, and to make tradeoffs among these requirements.

Testing and exercising of a BMD system would very probably require major growth in our current test range and space launch facilities. Given public resistance over the last two decades to the Safeguard and MX deployment schemes, the question of where to site such extensive facilities would need to be addressed at an early stage of the system design.

Constructing and maintaining a large space-based defense system would also require significant investment in space transport. These requirements would vary, of course, depending on whether the Soviets complicated our construction tasks by attempting to prevent or to delay our deployments. If we were to use space shuttles of roughly current capacity, the deployment of a comprehensive system over the period of a few decades would take at least several hundreds of flights, and probably more than a thousand. This would require an expanded ground-based infrastructure for launching and recovering shuttles, and a replenishment and repair infrastructure to replace and fix satellites. Because of the long lead times involved, a plan for space transport, replenishment, and repair should be part of a comprehensive BMD deployment plan.

Finally, of course, those elements of our defense system that are undergoing exercises or routine maintenance will not be combat-ready. A larger defense force with duplication of vital elements may therefore be needed to assure that some indispensable combination of elements is always operational.

CONCLUSION

While the political and scientific challenges posed by a comprehensive strategic defense system have been widely discussed since President Reagan's March 1983 speech, a third sphere—system capabilities—

has received less attention and yet involves challenges that are at least as great.

The sheer technical and operational complexity and scale of a multilayered BMD system, compounded with the changing threat and countermeasures it would give rise to, are daunting. The feasibility of a survivable and reliable system, with perfect or near-perfect performance, is far from certain. Research and experimentation in new systems architectures and subsystem designs are needed that can meet more limited objectives. The addition of BMD to our strategic posture would initially, and perhaps indefinitely, require a mix of both offensive and defensive forces each having more complex, diverse, survivable, sustained, and high-performance wartime capabilities than we now have. It is not yet clear whether such a mix of forces can provide stronger nuclear deterrence than the deterrent capabilities of an offense-only system.

The operational interactions of strategic offense and defense are complex and not yet well-enough understood for us to assess the cost-effectiveness of proposed BMD systems. Using new methodologies based on gaming and interactive simulation, we should investigate a number of mixes of offense and defense to assess which combinations might strengthen deterrence of nuclear attack while also minimizing generation of crises. The transition period to a well-developed, two-sided offense/defense situation would require decades, and uncertainties about effectiveness could continue even longer. Research is needed to understand better the dynamics involved in the relationship between stability and changes in military postures over time.

It is questionable whether multilayered BMD is the top priority defense problem facing the United States. The modernization of strategic offensive forces, or the readiness of all forces, for example, may be more important. Yet the development of BMD technologies and systems will have a significant effect on the availability of technologies and systems to these other national security areas. It might be possible, for example, to use laser weapons in air defense and conventional warfare or to employ space-based sensors capable of superior surveillance of space for warning and characterization of attacks. We will need to reappraise *all* our national security requirements continually, as we learn what is possible and feasible in BMD.

Assuring the performance of individual elements of a multilayered BMD system, and marshaling the effort and resources needed to develop, deploy, test, verify, and maintain an effective overall system will be an enormously complex and difficult task. Building such a system would dominate the defense and space activities of the United States for decades and would require extraordinary organizational and funding support. Given the potential costs and duration of the program, achieving and maintaining public support will be essential.

ENDNOTES

- ¹Senate Committee on Foreign Relations, *Strategic Defense and Anti-Satellite Weapons*, 98th Cong., April 25, 1984. This document contains the testimony of various administration witnesses and experts on the Strategic Defense Initiative. See also the Defensive Technologies Study Team (James C. Fletcher, et al.), *Report of the Study on Eliminating the Threat Posed by Nuclear Ballistic Missiles*, unclassified summary, Pentagon, March 1984; the Future Security Strategic Study (Fred S. Hoffman, et al.), *Defense Against Ballistic Missiles: An Assessment of Technologies and Policy Implications*, unclassified summary, U.S. Department of Defense, April 1984; and Ashton B. Carter, *Directed Energy Missile Defense in Space*, background paper, Office of Technology Assessment, U.S. Congress, April 1984. These three reports are reprinted in the *Senate Hearings*.
- ²Richard Nixon makes this point with respect to BMD: "Such systems would be destabilizing if they provided a shield so that you could use the sword," (*Los Angeles Times*, July 1, 1984). So did President Reagan in his March 23 speech: "I clearly recognize that defensive systems have limitations and raise certain problems and ambiguities. If paired with offensive systems, they can be viewed as fostering an aggressive policy; no one wants that."
- ³The cost-exchange ratio is the cost to the United States of preventing the expected damage if the Soviets send one more attacking warhead, against the marginal cost to the Soviets of sending that additional warhead. Some defense analysts believe that there is little prospect of achieving a cost-effective BMD in the foreseeable future unless the offensive threat is tightly constrained technically and greatly reduced numerically through offensive arms-control agreements. See, for instance, Donald Hafner's discussion of the Fletcher panel in this volume.
- ⁴Charles A. Zraket, "Strategic Command, Control, Communications, and Intelligence," *Science*, June 22, 1984.
- ⁵Brockway McMillan, et al., *Battle Management, Communications, and Data Processing* (vol. V of the Fletcher panel report, op.cit.). A line of computer code is a line of instructions, written in a form or "code" the computer can understand, telling it what the next step is it must perform.
- ⁶See Charles A. Zraket, et al., "SAGE—A Data-Processing System for Air Defense" and Herbert D. Benington, "Production of Large Computer Programs," in a special issue of the *Annals of the History of Computing*, Oct. 1983; Gustav E. Lundquist, *The United States National Airspace System*, NAS Stage A, proceedings of the International Symposium on Traffic Control, Versailles, France, June

1-5, 1970; Subcommittees of the Committee on Appropriations of the U.S. House of Representatives, *Hearings on the Safeguard Anti-Ballistic Missile System*, part IV, Department of Defense Appropriations for 1971.

⁷F. P. Brooks, *The Mythical Man-Month* (Reading, Mass.: Addison-Wesley, 1982), chap.8.

⁸See Herbert Lin, *Considerations in the Development of Software in BMD*, working paper of the Center for International Studies, MIT, Dec. 1984; and Barry W. Boehm, *Software Engineering Economics* (Englewood Cliffs, N.J.: Prentice-Hall, 1981), chaps. 5-9, describes the COCOMO model for estimating the amount of effort needed to produce software systems.

U.S. and Soviet Military Space Programs: A Comparative Assessment

SINCE THE LAUNCH OF SPUTNIK IN 1957, the United States and the Soviet Union have steadily expanded their military use of space to a point where they now rely heavily on satellites to enhance their national security. While space is often referred to as the “new high ground” or a “new dimension of the arms race,” there is nothing novel about its use for military purposes. Military satellites are used for reconnaissance, early warning, communication, navigation, weather forecasting, and geodetic data gathering. The current development of anti-satellite (ASAT) weapons and the growing interest in space-based ballistic missile defense (BMD) systems, however, clearly indicate a new trend in the militarization of space. Although it has been an integral part of the arms race between the superpowers for more than twenty-five years, space has generally been considered a “sanctuary” from the deployment and use of weapons.¹

While the United States and the Soviet Union both use space for broadly similar purposes, there are significant differences in the manner in which they utilize their satellites, and the value they choose to place on them. These differences will become especially important when we come to examine the implications of a conflict in space, implications that will force the superpowers to seek new precautions as threats to their satellites increase.

EVOLUTION OF THE U.S.-SOVIET MILITARY
EXPLOITATION OF SPACE

After a short period of uncertainty following Sputnik, when many feared and predicted that space would become an arena of superpower military competition, the United States and the Soviet Union settled down to a relatively stable relationship in their military exploitation of space. Compared with other areas of the arms race, and in sharp contrast to their rivalry in space exploration generally, the policies of both superpowers toward the military use of space has been remarkably free from competition. With few exceptions, both countries have developed space systems in accordance with their own terrestrial security requirements, rather than in response to the activities of the other. Moreover, the usual attributes of a military competition—the presence of weapons systems—has so far been absent from space. As military satellites are essentially supportive of or ancillary to activities on earth, space has remained, in effect, an adjunct to the arms race.

While military satellites are often regarded as “passive” because they are not lethal devices, they can enhance the lethality of other weapons and the effectiveness of military forces. This inherent duality, which has been aptly described as Janus-like, is apparent in the current applications of military satellites. Photographic and electronic reconnaissance satellites, for example, provide indispensable national technical means of verification for arms control and early warning of an attack. In this respect, they are considered benign and stabilizing. Yet they can also pinpoint military targets for attack during a conflict and provide valuable information for electronic countermeasures. Ocean reconnaissance satellites, on the other hand, do not have such redeeming virtues; their only function is to detect, track, and target naval vessels.

The U.S. nuclear explosion detection satellites were also initially developed to support arms control—specifically, to monitor compliance with the Limited Test Ban Treaty of 1963. While the latest system designed to detect nuclear bursts will continue to perform this role, its primary mission now is to facilitate post-attack assessment and re-targeting after a nuclear exchange. In other words, it has become an aid to warfighting.

Even communication, navigation, and weather satellites, which appear to be harmless, can be considered indirectly threatening to an adversary. Communication satellites may be able to increase a country's control over geographically dispersed forces and provide a valuable link for crisis management purposes, but in the same way they can also improve the overall performance of military forces. Space communication links, for example, provide the United States with an almost instantaneous method of collecting, collating, and disseminating information on the whereabouts of Soviet nuclear submarines, a capability that is obviously important for anti-submarine warfare (ASW) operations. Submarines, in turn, use navigation satellites to update their inertial guidance systems, which improves the accuracy of their ballistic missiles. These same satellites will increasingly be able to guide a range of strategic and tactical weapons to their targets with near-perfect precision. Meteorological satellites can be used to improve the effectiveness of military strikes by providing timely information about the weather over target areas. Even geodetic satellites, which map the earth's shifting gravitational fields, can provide valuable targeting data for strategic missiles. The only satellites that are unequivocally pacific are the early-warning systems that detect the launch of ICBMs and SLBMs. If ballistic missile defenses become a reality, however, these satellites will be used to acquire and track targets for interception and to assess the success of an engagement.

The dual nature of military satellites has become more apparent in recent years as the range of applications has expanded. For the first ten to fifteen years of the space age, satellites primarily benefited strategic forces, but since the mid-1970s, space systems have increasingly provided general-purpose forces with battlefield surveillance, communication facilities, and targeting information. The Soviet Union has as a rule lagged behind the United States in the development of military space technology, despite its early lead with Sputnik. Table 1 on the following page gives the dates for the introduction of various categories of U.S. and Soviet satellites and summarizes their current orbital deployments.

Despite a common appreciation of the benefits of military satellites, the U.S. and the Soviet Union have not always shared the same attitudes or policies towards the exploitation of space. Since the Second World War, four phases can be discerned.²

TYPE OF SATELLITE	TYPICAL DEPLOYMENTS		DATE OF FIRST DEPLOYMENT	
	U.S.	SOVIET	U.S.	SOVIET
PHOTOGRAPHIC RECONNAISSANCE	2-3 LOW ORBIT	1-5 LOW ORBIT	1959	1962
ELECTRONIC INTELLIGENCE (ELINT)	1-2 GEOSYNCH	6 LOW ORBIT	1962	1967
OCEAN SURVEILLANCE	6 LOW ORBIT	2-4 LOW ORBIT	1976	1967
EARLY-WARNING	3 GEOSYNCH	9 MOLNIYA	1960	1971
NUCLEAR DETECTION	6 SEMISYNCH ^a 2 SUPERSYNCH	??	1963	??
COMMUNICATIONS	11 GEOSYNCH 2 MOLNIYA	27 LOW ORBIT 12 MOLNIYA 12 GEOSYNCH	1959	1964
NAVIGATION	5 LOW ORBIT 6 SEMISYNCH ^b	10 LOW ORBIT 9-12 SEMISYNCH	1959	1967
METEOROLOGY	2 LOW ORBIT	3 LOW ORBIT	1963	1963

^aconsists of sensors on Navstar navigation satellites

^bthe Navstar navigation system will contain 18 satellites when completed

Table 1 Categories of U.S. and Soviet military satellites and year of first deployments; chart includes satellites dedicated to military use (some civilian satellites may also be used for military purposes). For definitions of different orbits, see pp. 148, 150.

EARLY VISIONS AND PREPARATIONS: 1945–1957

The potential military benefits of outer space were recognized as early as 1946 in the United States, but the dramatic contraction in the U.S. military budget after World War II discouraged experimentation in new ideas and research programs. Early satellite and ballistic missile development proposals, especially, fell victim to military conservatism induced, in part, by fiscal constraint. Without large boosters, there could be no space program.

By the early 1950s, though, attitudes began to change as the cold war intensified. The need for a more reliable source of strategic intelligence provided the *raison d'être* for reconnaissance satellites, and the demand for additional strategic delivery systems sparked interest in the ballistic missile program. Neither of these, however, was pursued very urgently. It is also ironic that the U.S. commitment in 1955 to launch a “scientific” satellite as a contribution to the International Geophysical Year (IGY) also hindered the progress of the U.S. space effort. Eisenhower’s decision to forbid the use of military boosters for the IGY program led to the disastrous choice of the Vanguard, a small and relatively undeveloped launch vehicle. Had the Eisenhower administration chosen the more advanced Army Orbiter project, with its Redstone (later Jupiter) rocket, the U.S. would have been the first country to place a satellite into orbit.

In contrast, ballistic missile development and the space program were receiving the highest political support in the Soviet Union. Not only was this compatible with the revolutionary scientific ethic, but strategic missiles offered a way to improve “the correlation of forces” with the West and an opportunity to reduce the size of Soviet conventional forces.³ Furthermore, Soviet Premier Nikita Khrushchev saw clearly the political and propaganda benefits of being the first country to launch an artificial satellite. While the U.S. program was proceeding slowly, handicapped by a self-imposed separation of military and civilian space research, the Soviets stole the lead in developing the world’s first intercontinental ballistic missile—the SS-6—and the world’s first artificial satellite, Sputnik.

EXPANSION AND UNCERTAINTY: 1958–1967

The immediate crisis of confidence caused by the Soviet coup de main in space led to a rapid expansion of the U.S. space program. Sputnik also generated considerable public anxiety that the Soviet Union might use space to threaten the United States. Believing that space represented a new dimension of warfare and that the emerging Soviet threat would need to be countered militarily, the armed services and the aerospace companies actively canvassed for a variety of space weapons, including anti-satellite devices, orbital bombardment systems, and space-based ballistic missile interceptors.

Preliminary research was carried out on many such proposals (including the world's first ASAT demonstration in 1959) as an insurance against hostile Soviet activities in space, but Eisenhower and, later, Kennedy rejected further development on the grounds that it would spur competition with the Soviet Union, and ultimately destroy the “peaceful” image the U.S. was trying to foster for its space program. Although both presidents genuinely wanted to prevent an arms race in outer space, their policy stemmed principally from a desire to legitimize U.S. satellite reconnaissance and reduce the likelihood of Soviet countermeasures.

This need to protect reconnaissance satellites became even more imperative when satellites became the primary source of strategic intelligence following the demise of U-2 overflights in May 1960. Despite some veiled threats, however, the Soviets never attempted to rebuff U.S. reconnaissance satellites in the same way they had the U-2 flights. Instead, in 1962 the Soviet Union introduced a resolution in the United Nations to outlaw “espionage” from space. The United States countered that satellite reconnaissance was a peaceful and legitimate use of space, thereby implicitly distinguishing it from non-peaceful and illegitimate activities. A vigorous U.S. space weapons program would only have contradicted and jeopardized this strategy.

Aside from this primary motive, space weapons offered few if any attractions to the United States at this time. Until an unequivocal Soviet threat developed in space, anti-satellite weapons had little use. As table 1 indicates, the Soviet military space program was still in its infancy. Orbital bombardment systems also offered no meaningful advantages over ballistic missiles as strategic delivery vehicles; if

anything they were inferior. Where a military rationale could be demonstrated, such as with space-based BMD systems, the United States considered further development prohibitively expensive and technically infeasible. The only exception to this stance came in 1963 when President Kennedy, as a precaution against the possible deployment of Soviet orbital bombs, authorized the development of two ground-based anti-satellite systems, one using the Nike Zeus ABM missile and the other the Thor IRBM. No more than a handful of these missiles were ever deployed. Although the Thor system remained operational until 1975, its fixed launch site and nuclear warhead severely limited the circumstances in which it could be used.

The Soviet Union dropped its opposition to satellite reconnaissance in the fall of 1963. At the same time, it also agreed to a U.N. resolution banning the deployment in space of weapons of mass destruction. This resolution subsequently became the basis for the Outer Space Treaty, signed in 1967. Although there were some remaining doubts, particularly when the Soviet Union began testing a fractional orbital bombardment system (FOBS) in 1966, it appeared to many that the Soviets had accepted—if only tacitly—the U.S. conception of space as a sanctuary from certain military activities.

This was partly true. Soviet diplomatic efforts to ban satellite reconnaissance had failed to gain wide support in the U.N., and the use of force against U.S. satellites would not have been easy. More important, continued opposition to reconnaissance from space would have been counterproductive to the Soviet Union's own satellite reconnaissance program, which began to return photos in 1962. The overriding requirement of responding to the Kennedy administration's offensive strategic buildup no doubt made further confrontation and a potential military competition in space especially undesirable for the Soviets. Nonetheless, they still considered it prudent to take out some technological insurance, and, in the process, gain the ability to counter U.S. space systems in the event of war. For all these reasons, the Soviet Union in the early 1960s embarked on a satellite interceptor program.

CONSOLIDATION AND STABILITY: 1968–1975

It was testament to the stability of the apparent *modus vivendi* in space that even when the Soviet Union began testing its satellite

interceptor in 1968 the United States seemed remarkably unalarmed—something that would have been unthinkable a few years earlier. The little concern that did exist soon dissipated when the Soviets ceased their ASAT tests at the end of 1971 and conducted no further tests for the next four-and-a-half years. The United States was also encouraged by the progress of detente, which produced a number of agreements reinforcing the tacit ground rules for the military exploitation of space. The SALT I interim agreement, signed in 1972, contained important clauses prohibiting interference with national technical means of verification, including satellites. The ABM treaty signed at the same time also banned the testing and deployment of BMD systems in space.

After the rapid expansion of the early 1960s, the U.S. military space program settled into routine operation. The sophistication of satellites improved steadily, but the general level of space activity dropped off from its frenetic pace at the beginning of the decade. Even the space budget began to decline in real terms. These trends were partly due to greater efficiencies in the space program, and partly to the military's shift in attention away from space to the war in Southeast Asia.

The Soviet space program, on the other hand, underwent rapid expansion in the late 1960s, deploying new types of satellites with greater frequency. By the early 1970s, Soviet space activity had surpassed that of the United States in both number of launches and total payloads orbited. Soviet use of reconnaissance satellites during the major international conflicts of this period indicated clearly that space systems were becoming an integral part of Soviet crisis monitoring and, ultimately, Soviet war planning.

THE EMERGING ARMS RACE IN SPACE: 1976 TO PRESENT

By 1976, the increasing military use of space on the part of the Soviets had become a source of concern to the United States. This concern in many respects mirrored the U.S. reaction to the Soviet strategic buildup that also occurred during this period. The resumption of Soviet satellite interceptor tests in 1976 was the primary catalyst for the United States' reconsideration of the usefulness of anti-satellite weapons. While the new Soviet tests were not markedly different from the earlier series (and if anything had an inferior performance),

the tenor of U.S.-Soviet relations had changed significantly. The Soviet attainment of strategic parity and its perceived adventurism in the Third World made the United States especially sensitive to any new Soviet military activities. As a result, President Gerald Ford in one of the last acts of his administration authorized the development of a new U.S. anti-satellite system. While the ostensible rationale was to counter the indirect threat from Soviet military satellites—especially ocean reconnaissance satellites—the real reason appears to have been an unwillingness to accept any imbalance in U.S.-Soviet ASAT capabilities.

President Jimmy Carter continued with the ASAT R&D program to gain bargaining leverage in ASAT arms-control negotiations and to provide insurance in case such negotiations failed. Three rounds of ASAT negotiations were held in 1978–79, but no agreement was reached. Although some progress was made, differences over the scope of an agreement, the diversions of the SALT II debate, and the suspension of arms-control negotiations following the Soviet invasion of Afghanistan thwarted any chance of success.

For nearly four years, the Reagan administration opposed resumption of ASAT negotiations, despite the Soviet Union's announcement of a unilateral testing moratorium and its proposal of two space weapons treaties to the United Nations. By the summer of 1984, however, growing congressional pressure and concern over the possible electoral repercussions resulting from an alarming deterioration in U.S.-Soviet relations forced the Reagan administration to reconsider its stance on the ASAT issue. A Soviet offer to begin discussions in September 1984 came to naught when the sides could not agree on the scope of the talks nor on an ASAT test moratorium. The Soviets wanted to include all space weapons and to impose an immediate test ban—an obvious effort to restrict the U.S. ASAT program and the BMD research provided by the Strategic Defense Initiative. The United States insisted on at least testing its new ASAT system—the air-launched miniature vehicle—before considering any ASAT limitations, and it insisted the talks should cover strategic and theater nuclear forces as well. Following the 1984 presidential election, a U.S. proposal for “umbrella” arms-control discussions, to include space weapons, was accepted by the Soviets. While some type of agreement relating to space weapons cannot be discounted, the

prospects for meaningful limitations are being progressively undermined by the pace of ASAT research and development.

A COMPARATIVE ASSESSMENT OF U.S. AND SOVIET MILITARY SPACE PROGRAMS

Since outer space offers the same inherent opportunities to both the United States and the Soviet Union, it is not surprising that they should eventually find themselves using satellites for broadly similar purposes. There are real distinctions, however, between the two countries' programs. The most noticeable difference is the rate at which each country launches payloads into orbit. Throughout the 1960s, the United States led the Soviet Union both in total space launches and total payloads. During the 1970s, however, the number of U.S. space launches progressively declined, while that of the Soviets increased. In 1984, the Soviet Union conducted ninety-seven launches, of which 80 percent were identified as military related; the United States had twenty-three launches, of which 39 percent were for military purposes. These statistics are often cited to highlight the dynamic nature of the Soviet space program and indicate implicitly that the United States has fallen behind in the exploitation of space. Actually, a high rate of launches is more indicative of a lower capability. As the U.S. Department of Defense states, the fact that the "Soviets routinely conduct about four to five times as many space launches per year as the United States . . . is necessitated primarily by the shorter system lifetimes and poorer reliability of most Soviet satellites."⁴ For example, Soviet reconnaissance satellites, which account for nearly 60 percent of all its military space launches, stay in orbit on average only about three weeks.⁵ Most of these satellites are deliberately returned from orbit to recover the exposed film. In contrast, the two main U.S. systems, the KH-9 (Big Bird) and the KH-11, last approximately thirty-five weeks and one hundred weeks respectively. The KH-9 returns its film by recoverable capsules, and the KH-11 transmits images electronically. Although these two recovery methods were mastered by the United States in the 1960s, the Soviets began to use recoverable capsules only during the late 1970s and are only now developing an electronic transmission system. The additional argument that the Soviets' higher launch rate

better enables them to replace satellites that are lost during hostilities may be true, but this smacks of making a virtue out of necessity.

Another reason the Soviets have a higher launch rate is because it generally takes a greater number of Soviet satellites to provide the same level of service as their U.S. counterparts. For example, the Soviets maintain three distinct constellations of satellites for the purposes of space communication, two for tactical and one for strategic communication. The tactical communication satellites are small and simple, operating at low altitudes. They are what is known as “store dump” satellites—they receive information as they pass over one part of the globe, transmitting it later at an appropriate time and place; they are not used for urgent communications. For these low-altitude satellites to provide continuous coverage of the world, the Soviets must cluster them into two constellations, with three satellites in one constellation and twenty-four in the other. In addition, the Molniya strategic communication system contains another twelve satellites, in a highly elliptical orbit, that provide continuous coverage of the northernmost latitudes of the Soviet Union where many of the country’s key military installations are located. Because of the curvature of the earth, geostationary communication satellites placed 36,000 kilometers above the equator would not provide satisfactory coverage of these areas. More recently, the Soviets have begun using geostationary satellites for communication, some of which is almost certainly military related. In contrast, except for two Satellite Data System (SDS) satellites used for polar communications in an orbit similar to the Molnias, U.S. tactical and strategic military communications are handled by approximately eleven high-capacity, long-lasting geostationary satellites. The United States also uses the geostationary orbit for early warning and electronic intelligence-gathering satellites.

Besides these differences in the duration and distribution of U.S. and Soviet satellites, there are other practices that distinguish the two space programs. U.S. satellites more often perform dual functions: the Navstar GPS (global positioning system) navigation satellites and the Defense Support Program (DSP) early-warning satellites also carry nuclear-explosion detectors, other satellites carry special strategic communication transponders, and the Defense Department’s meteorological satellites carry a variety of sensors with different applica-

tions.⁶ Such multipurpose satellites are not common in the Soviet space program.

The Soviet Union, on the other hand, has placed greater emphasis on manned military space operations. The manned Salyut space station has been used for reconnaissance purposes and possibly for other military-related experiments. Currently, the only manned U.S. spacecraft is the space shuttle, which stays in space for relatively short periods to ferry satellites into orbit. The U.S. Air Force will begin shuttle operations from its Vandenberg launch complex in late 1985 or 1986. The Soviet Union is currently working on its own shuttle, but a full-scale vehicle has yet to be tested.

RELATIVE DEPENDENCE ON MILITARY SPACE SYSTEMS

Assessing the relative importance of military space systems to the two superpowers is considerably more difficult than comparing their operational styles. It has often been said that the United States is more dependent than the Soviet Union on the services of military satellites. Statements about the relative dependency on satellites, however, must be interpreted with some care. To begin with, there is a vital difference between dependence based on choice, and dependence based on necessity. While satellites may be relied on to support certain missions, there may be other ways to achieve this. Also, in situations where satellite service is unique, it may not be critical or always important. The amount of dependence therefore varies with the different types of satellites, with their peacetime and wartime roles, and with the circumstances in which they are used. While it is true that accounting for all these variables requires a more complicated assessment, it would be undeniably more meaningful than merely "static" comparisons. This can be illustrated by examining four categories of satellites: reconnaissance, communication, early warning, and navigation.

Reconnaissance Satellites

Given the closed nature of Soviet society, the United States is more dependent on reconnaissance satellites for its strategic intelligence gathering and for verification of arms-control agreements. In the United States, no other method of verification can rival in importance the use of photographic and electronic reconnaissance satellites. We

must be careful not to exaggerate, however, this difference between the superpowers. The Soviets, too, rely on satellites for monitoring activities in China, for strategic targeting, and for corroborating information gained from other intelligence sources. The Soviets also depend on satellites for crisis monitoring, as indicated by changes in the orbits of Soviet reconnaissance satellites and their higher launch/recovery rate during major international conflicts. The United States, on the other hand, can use high-altitude reconnaissance aircraft deployed at numerous bases around the world. The Soviets also have long-range reconnaissance aircraft, but they do not have as many bases worldwide and therefore cannot achieve as much coverage.

Levels of dependence on reconnaissance satellites during wartime are more difficult to assess. It is likely that satellites will play a vital early-warning role before hostilities, but subsequent use will depend on the geographic location of the conflict and the type of warfare. For example, the initial dependence on satellites during a conventional war in Europe would likely be low because ground-based in-theater reconnaissance systems, such as aircraft and, in the future, remotely piloted vehicles, would be available. Given the expected high attrition of these systems, however, satellites may become the primary source of information in a prolonged conventional war, provided that the equipment necessary to receive and use the data survives. In conflicts occurring outside Europe or the immediate periphery of the superpowers, conventional reconnaissance systems may be less available, creating greater dependence on satellites. Since the United States—with its global military presence and large number of overseas bases—is likely to have more alternatives available to it than the Soviet Union, it will probably have a lower overall dependence on satellites.

In the event of a nuclear war, the relative importance of reconnaissance satellites will depend heavily on the role that each country envisages for its space-based systems, and on the length and intensity of hostilities. The development of satellites designed specifically for post-attack assessment reflects a desire on the part of the U.S. to ensure flexible and discrete nuclear attack options to meet a variety of contingencies. In contrast, as one analyst has pointed out, Soviet doctrine favors massive initial attacks and evinces little concern for post-attack assessment and follow-up attacks.⁷ After a prolonged

nuclear exchange, satellites arguably cease to have much relevance, especially as the ground-based centers that receive and use their data will almost certainly be destroyed.

Communications Satellites

A statistic often cited to illustrate U.S. dependence on space systems is that more than 70 percent of all U.S. military communications are transmitted via satellite. Again, such a figure is meaningful only when put into proper perspective. In peacetime, a good deal of routine message traffic passes through military communication satellites simply because they offer an inexpensive way to transmit information. In wartime, when message traffic would be pared down to a vital minimum, satellites may be useful, but not necessarily critical; there are other ways of communicating information, including a variety of dedicated military radio systems and civilian channels.⁸ Here again, geographical factors will determine the alternatives available to both sides with Soviet dependence on satellite communication likely to be higher than that of the United States in geographically remote areas.

Considerable redundancy also exists among methods of communicating with strategic nuclear forces. The Soviet Union has invested massively in redundant command, control, and communication facilities—including an extensive network of buried cables and radio relay systems—many of which appear to be designed to function during and after a nuclear war.⁹ The United States, similarly, has a wide range of strategic systems to ensure unbroken communication at least in the initial stages of a nuclear war.¹⁰ On the face of it, therefore, dependence on space systems for strategic communication appears to be low for both countries. This may change, however, as both sides begin to rely more heavily on highly dispersed and mobile strategic forces.

Early-Warning Satellites

It is difficult to predict which superpower would benefit more from the extra warning time provided by early-warning satellites. The low peacetime alert rates of the Soviet strategic forces suggest that they would gain more. Yet early-warning satellites can provide only tactical warning, so the benefits may be marginal, at best, for strategic

forces not already on alert. While the Soviet bomber force would need early warning to get off the ground before an attack, the greater role bombers play in U.S. strategic forces suggests that early warning might be comparatively more important to the United States. The flight times of forward-deployed SLBMs and INF missiles are so short, however, that even the extra warning time provided by satellites may not be sufficient for bombers to clear their bases before attacking warheads arrive.

Navigation Satellites

Both the United States and the Soviet Union are deploying remarkably similar satellite navigation systems (Navstar GPS and GLONASS, respectively). This appears to indicate that the two nations have an equal interest in, and place equal importance on, navigation systems. But apart from its ability to pinpoint nuclear explosions, Navstar will almost certainly have a wider range of applications at both the strategic and tactical levels, making it the more valuable of the two (it has already demonstrated its ability to guide “dumb” weapons with the same accuracy as inherently “smart” precision-guided munitions).¹¹

In conclusion, while space is clearly important to both the U.S. and the Soviet Union, the relative dependency on satellites varies between different categories of satellites and in different contingencies.

FUTURE APPLICATIONS

The importance of space shows every indication of growing in the years ahead as the military applications of satellites continue to expand. At the tactical level, the use of satellites to detect aircraft and direct air defenses—a role very similar to that performed by AWACS—is currently being considered. Local commanders will also be able to use such satellites for deep strike operations. With the added precision of navigation satellites, long-range military targets can be attacked with high confidence of success. High-accuracy theater and strategic missiles will also increase the potential for preemptive counterforce attacks. Perhaps the most portentous development will be the use of satellites for strategic anti-submarine

warfare operations. Current efforts to develop space-based sensors that would make the ocean depths transparent will undermine the last truly invulnerable segment of the strategic triad. The impact of such systems, however, might be mitigated by the deployment of ballistic missile defenses. Regardless of the final configuration of a BMD system—whether for limited point defense or comprehensive population protection—space systems will be used for the early detection, tracking, and discrimination of attacking warheads. More ambitious systems would make outer space the first line of defense, through orbiting or “pop-up” battle stations.

Although the trend towards relying heavily on space systems to support a wide range of military missions will continue in the foreseeable future, the wisdom of pursuing this course must be evaluated in light of their growing vulnerability to a determined adversary’s countermeasures.

VULNERABILITY AND PROTECTION OF SPACE SYSTEMS

The expanding role of military satellites has naturally increased their attractiveness as military targets. Weapon systems designed specifically to disable satellites, however, represent just one approach among several for thwarting a satellite’s usefulness. Since every satellite is part of a complex web of communication links and ground facilities, it is vulnerable on a number of fronts—a fact well appreciated by the designers of ASAT systems. For example, the mission payload (such as sensors or communication transponders), power source (solar cells or a nuclear generator), communications package, and control system, which are all essential for the satellite’s continuing operation, are vulnerable to specific ASAT efforts. The satellite itself can be threatened by homing vehicles, fragmentation warheads, directed energy weapons, and the effects of a nuclear blast.

The radio communication links to and from a satellite, which are required for routine station-keeping and the transmission of mission-related information, are also vulnerable to the effects of nuclear explosions, electronic jamming, “spoofing” (the giving of false commands and information), and “takeover” (unauthorized use by an adversary). Finally, the ground sites of a space system, which include launch sites, space surveillance networks, command-and-control

centers, and receiver stations, are vulnerable to direct military attack and terrorist activities.

Given the variety of methods for disabling or interfering with satellites, a distinction is often made between *dedicated* ASAT systems (i.e., weapons designed solely or primarily for this purpose, such as the current U.S. and Soviet ASAT systems) and *residual* systems (i.e., weapons that have a dual or potential ASAT capability such as long-range missiles, electronic jammers, and ABMs).

Although the threats to space systems are therefore numerous, there are many ways that a country can prolong the survival of its satellites. The first method at its disposal is deterrence of a potential aggressor. As in all relationships based on deterrence, it is necessary that the side wishing to protect its space systems has a credible retaliatory capability, and that the attacker has a meaningful stake in the uninterrupted use of his own satellite services. If the latter is uncertain, the threat of retaliation could instead be made against whatever *non-space* systems are most highly valued by the attacker.

A second method is defense of the satellite and support systems by active and passive means. Active measures are designed either to destroy a threatening ASAT system—for example, with shoot-back lasers or interceptors—or to deflect, deceive, or evade an attack through the use of jammers, flares, decoys, and emergency maneuvering systems. Passive defensive measures—armoring the satellite against nuclear effects and directed energy weapons, adding anti-jamming devices and sensors to warn of an ASAT attack, and increasing the autonomy of satellites to avoid dependence on instructions from ground stations—can also be employed.

The survivability of a space system can be further enhanced by the use of reconstitution or redundancy of individual satellites. This involves either replacing disabled satellites with spares already prepositioned in space, or developing an emergency launch-on-demand capability. Communication links can be maintained by internetting procedures, while the vulnerability of ground terminals can be reduced by mobile systems. The ability to switch to non-space alternatives without creating a meaningful drop in performance would place a country in an extremely advantageous position. (See table 2, next page, for illustration of how survivability countermeasures offset threats to a space system.)

SPACE SYSTEM SEGMENT	THREAT	PROTECTIVE COUNTERMEASURES
ORBITAL SEGMENT	ICBMs NUCLEAR: SLBMs ABMs	ELECTROMAGNETIC PULSE (EMP) SHIELDING, NEUTRON HARDENING, IN-ORBIT SPARES, GROUND BACKUPS
	FRAGMENTATION NON-NUCLEAR: CHARGES IMPACT WEAPONS DIRECTED ENERGY: LASERS, ETC.	WARNING SENSORS AND MANEUVERABILITY, FLARES, JAMMERS, IN-ORBIT SPARES, GROUND BACKUPS, REFLECTIVE COATINGS/SHIELDING
LINK SEGMENT	JAMMING	ELECTRONIC COUNTERMEASURES (ECM), FREQUENCY HOPPING, ANTENNA NULLING, GREATER SATELLITE AUTONOMY
	TAKEOVER	AUTHENTICATION (ENTRY CODES, ETC.)
	SPOOFING	ENCRYPTION
GROUND SEGMENT	MILITARY OR TERRORIST ATTACKS ON:	
	LAUNCH FACILITIES	REDUNDANT FACILITIES, SECURITY PRECAUTIONS, HARDENING, REPLACEMENT LAUNCHES FROM SLBMs OR ICBM SILOS
	SPACE SURVEILLANCE RADARS AND TELESCOPES	REDUNDANT FACILITIES, INTERNETTING
	COMMAND-AND-CONTROL FACILITIES	MOBILE SYSTEMS, SATELLITE AUTONOMY

Table 2 Threats to Space Systems and Protective Countermeasures

Although a wide range of survivability options exists, the efforts devoted to satellite survivability must be kept in proportion to the nature and probability of the threat, and the value of the satellite. While it is obviously desirable to protect a satellite against a crippling “cheap shot,” ensuring survivability becomes progressively difficult and expensive as the ASAT threat grows and becomes more sophisticated. Beyond a certain threshold, it would probably be simpler and cheaper to build low-cost reconstitutable satellites or use non-space alternatives, rather than attempt to protect each and every existing satellite against the whole host of ASAT techniques.

*

*

*

The militarization of space has resulted in what many regard as two incompatible trends: the first is the steady expansion of the role of military satellites; the second is the inevitable response of anti-satellite weapons. This raises a dilemma. To continue to rely on increasingly vulnerable space systems is to court disaster. Yet, to restrict the development of ASAT weapons is to make outer space safe for potentially threatening satellites.

In a sense, though, the alternatives are not actually this stark. It is true that if the number of dedicated ASAT weapons were controlled, the existence of residual ASAT capabilities would still pose a threat to satellites. Nonetheless, we face a fundamental choice: we can enjoy the benefits—and tolerate the attendant hazards—of allowing satellites to operate in a relative sanctuary; or we can opt for a situation in which the full potential of space will never be exploited because we are reluctant to expose our satellites to the threat of unrestrained ASATs. Such a choice can only be made after careful weighing of the benefits and hazards satellites pose to our country. This choice is fast becoming moot, however, as the development of space weapons gains momentum, and reduces the likelihood of meaningful arms control.

ENDNOTES

- ¹The term “sanctuary” needs some qualification: both superpowers have had the capability, from the beginning of the space age, to disrupt and disable satellites with electronic jamming or by detonating nuclear warheads nearby.
- ²Unless otherwise stated, information for the following section is taken from Paul Stares, *The Militarization of Space: U.S. Policy 1945–1984* (Ithaca, N.Y.: Cornell University Press, 1985).
- ³See Robert P. Berman and John C. Baker, *Soviet Strategic Forces: Requirements and Responses* (Washington, D.C.: The Brookings Institution, 1982), p. 46–47.
- ⁴U.S. Department of Defense, *Soviet Military Power*, 3rd ed. (Washington, D.C.: Government Printing Office, 1984), p. 46.
- ⁵See Nicholas Johnson, *The Soviet Year in Space: 1983* (Colorado Springs: Teledyne Brown Engineering Corp., 1984), p. 10.
- ⁶Thomas Karas, *The New High Ground: Strategies and Weapons of Space Age War* (New York: Simon and Schuster, 1983), pp. 137, 145.
- ⁷See Stephen M. Meyer, “Soviet Military Programmes and the ‘New High Ground,’” *Survival*, Sept.–Oct. 1983, p. 207.
- ⁸For a comprehensive discussion of the variety of communication systems used by the superpowers, see William M. Arkin and Richard Fieldhouse, “Nuclear Weapon Command, Control and Communications,” in *SIPRI Year-Book 1984* (London: Taylor and Francis, 1984), pp. 455–516.
- ⁹See Colin S. Gray, *American Military Space Policy: Information Systems, Weapon Systems and Arms Control* (Cambridge, Mass.: Abt Books, 1982), p. 5.
- ¹⁰Charles A. Zraket, “Strategic Command, Control, Communications, and Intelligence,” *Science*, June 22, 1984, pp. 1306–1311.
- ¹¹See U.S. Congress, Senate Subcommittee of the Committee on Armed Services, *Department of Defense Authorization for Appropriations for Fiscal Year 1981*, 96th Cong., 2nd sess., part 5, 1980, p. 2674.

Anti-Satellite Weapons: Weighing the Risks

THE MISSION OF ANTI-SATELLITE WEAPONS (ASATs) is to destroy vital components of an adversary's network for intelligence gathering and for the command and control of his own forces. This raises a fundamental question: does the military usefulness of ASATs overshadow their capacity for exacerbating crises and conflicts? Any device that is able to destroy satellites has this dual nature; its targets' roles change dramatically as the world moves from peacetime, through crisis, to war. Satellites that can transmit images of military units electronically (in "real time") could be invaluable during negotiations to resolve a crisis and in building confidence that promises are being kept. Yet if diplomacy should fail, that same data could be used to optimize attack. A similar ambiguity characterizes satellites that give early warning of missile launches: in peacetime they provide reassurance, but in war they could be used to help target a retaliatory strike.

ASATs play a correspondingly complex role. On the one hand, they enhance a nation's military capability and thereby its ability to deter attack; on the other hand, the very fear of an ASAT attack on vital satellites could contribute to the escalation of a crisis or low-level conflict. An evaluation of ASATs must consider how they will affect this delicate balance between the somewhat contradictory goals of fighting a war, and preventing one.

This article will seek to strike that balance by examining the possible military and political roles of ASATs in a variety of crises and conflicts. To do this, we shall have to distinguish between the near

and long term, since ASAT technology is still in its infancy. Assessing future confrontations involving systems that do not yet exist is a speculative venture. Nevertheless, we still conclude that all the technological trends indicate that ASATs possess a considerably greater capacity for transforming a crisis into a war, and for enlarging wars, than they do for assisting in military missions or enhancing deterrence. Given this conclusion, we shall argue that our security would best be served by a comprehensive ASAT test-ban treaty, complemented by feasible satellite protective measures.

SATELLITES AND ASATS

ASATs do not currently pose a threat to all satellites, though by the next decade they might be able to. At the moment, the vulnerability of satellites is in large measure determined by their orbit. These orbits can be divided into four distinct categories, as shown in table 1, opposite.

Low orbits. Satellites in orbits below 5000 kilometers are the only ones vulnerable to the current generation of ASATs. Both superpowers use such orbits for photo-reconnaissance, electronic intelligence (ELINT), meteorology, geodesy, and manned spacecraft. The Soviets also use these vulnerable orbits for some communications satellites and for their radar ocean surveillance satellites.

Highly elliptical, or Molniya orbits. Satellites in Molniya orbits are used extensively by the Soviets for strategic early warning and for military and civil communication. Because these satellites remain in sight of ground stations at northern latitudes for about eight of their twelve-hour orbital periods, they would be potentially vulnerable to the forthcoming U.S. ASAT, if the United States should stage its attacks in the Southern Hemisphere where Molniya satellites dip to their lowest altitudes. To counter this threat, the Soviets could conceivably use geosynchronous satellites instead, and relay signals through semi-synchronous satellites to reach ground stations at high latitudes.

Semi-synchronous orbits. Satellites in these orbits, at altitudes of about 20,000 kilometers, are beyond the range of ASATs expected to

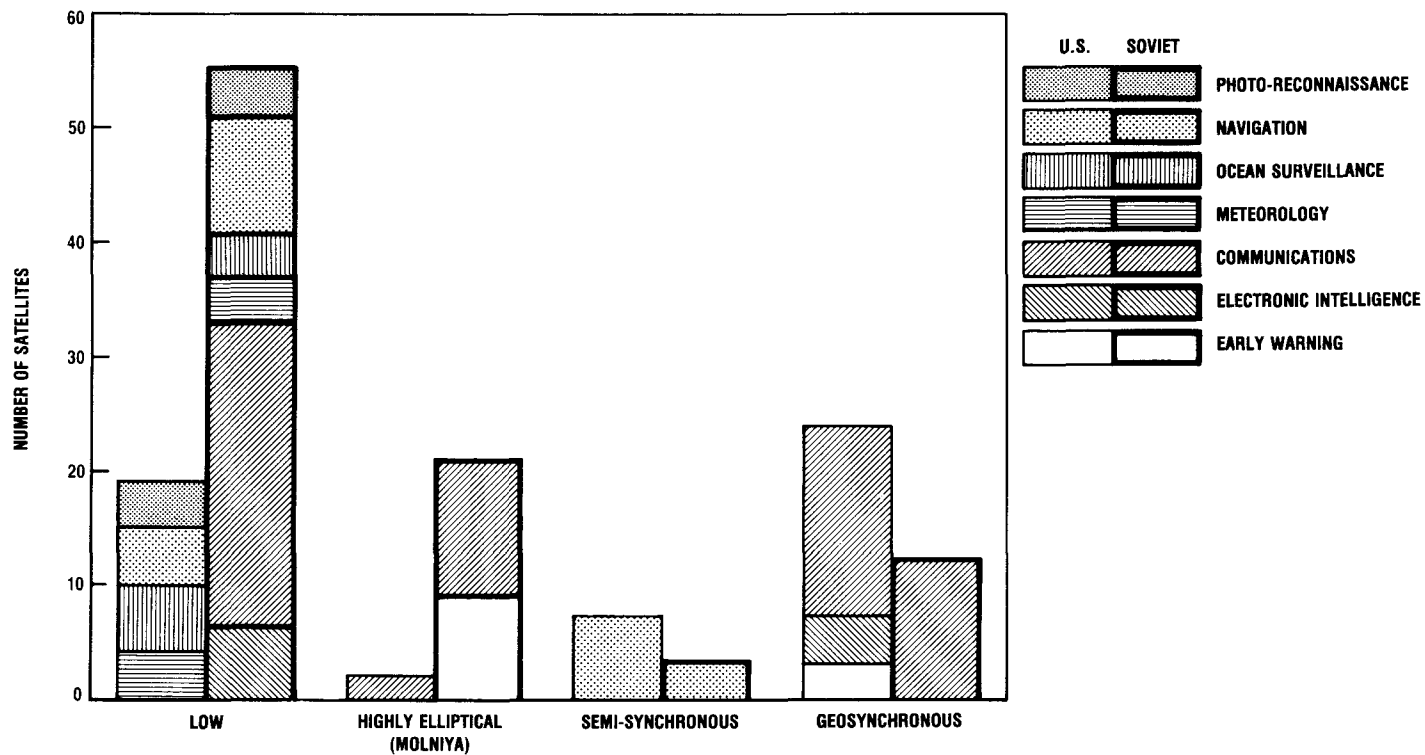


Table 1 Typical constellations of military satellites deployed by the United States and Soviet Union at any given time (includes some civilian satellites with military capabilities). The current generation of anti-satellite weapons threatens only those satellites in low orbits.

be operational in this decade. The U.S. Navstar system, which is expected to be fully operational by 1987, is now being placed in such orbits, as is the similar Soviet GLONASS system. These navigation satellites will enable military forces to determine their own location and deliver their weapons with remarkable accuracy.

Geosynchronous orbits. Satellites in these orbits, at an altitude of 36,000 kilometers, circle the earth at the same rate as the earth's rotation and remain above a fixed point on the equator. Satellites in such high orbits are invulnerable to current ASAT systems. The United States exploits such orbits for strategic early warning, electronic intelligence, and military communication. At present, the Soviet Union has only communication satellites in such orbits, but by the next decade it is expected to have a wider array of geosynchronous satellites.¹

CURRENT ANTI-SATELLITE WEAPONS

The current Soviet ASAT is a massive device weighing more than 2000 kilograms. It is lofted into orbit atop a liquid-fueled booster derived from the old SS-9 ICBM. In all past tests, the Soviets have launched the ASAT from two pads at the Tyuratam test range. After launch, the ASAT completes one or two trips around the earth, its orbit is changed to cross that of the target, the ASAT conducts final interception maneuvers under the guidance of an on-board homing device, and its warhead explodes into pellets directed towards the target. The U.S. Defense Department estimates that the Soviet ASAT is capable of intercepting satellites in orbits up to 5000 kilometers; the highest intercept ever attempted in a Soviet test has been only 1600 kilometers.

The first test of the Soviet ASAT took place in 1968, and the twenty tests since then can be classified according to the interception technique used.² In the first group, the ASAT intercepted targets on its second orbital pass, using an active radar homer. Out of ten such tests, seven succeeded. About three hours elapse between launch and interception in these second-orbit attacks; this gives a U.S. satellite opportunity for evasive maneuvering or jamming of the ASAT's radar homer. It was these considerations that presumably led the Soviets, in two other groups of tests, to attempt first-orbit intercepts with the

radar homer, and second-orbit intercepts with an optical/infrared homer that detects the target's heat radiation and is not so easily foiled. In the first-orbit intercepts, four tests produced two successes; in the optical/IR homing tests, six tests yielded not a single success.

In addition to its poor test performance, the Soviet ASAT suffers from several inherent limitations. First, it can attack a satellite only when the target's ground track runs close to the ASAT launch site, which happens just twice a day; this means waiting an average of six hours to attack a given satellite. Second, the ASAT's heavy weight requires a massive booster; it can therefore only be launched from a few Soviet facilities. Third, it is difficult to fire such massive liquid-fuel boosters in rapid succession from a single launch site.

Taken together, these limitations lead informed observers in the U.S. to estimate that it would take the Soviet ASAT force a week or more to destroy those American low-altitude satellites that are theoretically within its reach, although it may take only several days to eliminate essential ELINT and photo-satellites. Attacking satellites at 20,000 kilometers or higher would require a much more massive booster rocket, and probably modifications and improvements to the interceptor as well. Furthermore, the ASAT would give ample warning of its attack, since it would take several hours to reach such altitudes.

An assessment of the threat posed by the Soviet ASAT was given several years ago by General Lew Allen, then Air Force chief of staff: "I think our general opinion is that we give it a very questionable operational capability for a few launches. In other words it is a threat we are worried about, but they have not had a test program that would cause us to believe it is a very credible threat."³ Nothing that has happened in the Soviet test program since that assessment would suggest that the threat has increased.

The current U.S. ASAT program was begun by the Air Force in 1977. The ASAT's mission, as announced by the Carter administration, was to deter the Soviets from using their ASAT by threat of retaliation, to protect U.S. military units from observation by Soviet satellites, and to induce the Soviet Union to reach an ASAT arms-control agreement.

The U.S. Air Force ASAT weapon is launched by a two-stage rocket small enough to be carried to high altitude by an F-15 fighter. This rocket boosts a device known as a miniature homing vehicle into the path of the target satellite, using data on the target's path supplied by

the ground-based satellite tracking network. The homing vehicle itself is a squat cylindrical object weighing about 15 kilograms. It has infrared sensors able to “see” the target against the cold background of space, and a set of small thrusters that can be fired to bring the cylinder into the path of its target. The resulting high-speed collision destroys the target. The maximum altitude of the U.S. ASAT has not been revealed, but the joint chiefs of staff have stated that the highest priority targets are Soviet satellites that can locate American forces—presumably photo-reconnaissance, ELINT, and ocean surveillance satellites at altitudes of 500 kilometers or less.

If it performs as it is supposed to, the U.S. ASAT will be more versatile and capable than its Soviet counterpart. In principle, any F-15 can be adapted to carry the ASAT. Furthermore, carrier-based aircraft, or mid-air refueled F-15s, can carry the ASAT to an attack position almost anywhere in the world. In contrast to the Soviet ASAT, the U.S. weapon does not go into orbit but ascends directly towards its quarry, thereby giving it little opportunity for evasion. If the United States were to invest in extensive tracking, control, and communication facilities, it could acquire an ASAT force able to destroy all Soviet low-orbit satellites in a matter of hours.

Although the Air Force is charged with the anti-satellite mission, the Army’s Ballistic Missile Defense Program also contributes to the United States’ ASAT capability. In the Army’s Homing Overlay Experiment of 1984, an infrared-homing interceptor launched from Kwajalein destroyed a dummy ICBM warhead at an altitude of more than 150 kilometers. Since a satellite is much larger and more fragile than a warhead, there is no question but that this weapon has an ASAT potential. Indeed, this experiment indicates that the United States and Soviet Union have now tested rather similar ASAT weapons. Both weapons have the handicap of being launched by ground-based ICBM boosters, though the U.S. homing overlay interceptor exploits an infrared homing device that the Soviets have not yet mastered.

FUTURE ANTI-SATELLITE WEAPONS

In addition to these existing weapons, other ASAT techniques have been proposed, including space mines and directed energy ASATs. A space mine would be a satellite containing explosives, placed in orbit

well in advance of a conflict. When detonated by remote command (or on being tampered with), it would destroy its target. In principle, space mines could threaten satellites at all altitudes. However, if the target satellite had on-board sensors and could maneuver effectively, the space mine would have to be a sophisticated device, perhaps more complicated than current ASATs, in order to stay near its target. A possible drawback of the space mine is that its placement alongside another superpower's satellite could, in and of itself, trigger a confrontation.

There has also been much interest in anti-satellite weapons that exploit directed energy (laser or neutral particle) beams. Both the United States and the Soviet Union now have laser demonstration projects that could be turned to ASAT purposes. Directed energy concepts primarily intended for space-based ballistic missiles defense would, if pursued, also have a significant ASAT potential. Even though the energy deposited on a target by a directed energy weapon decreases sharply with distance, a laser or neutral particle BMD weapon able to destroy a missile in a matter of seconds could also deposit enough energy, at a high enough rate, to damage unprotected satellites in geosynchronous orbits. In this regard, it is essential to recognize that even an ineffective space-based BMD system could be a potent ASAT, while an effective BMD system would, as a matter of course, be an ASAT system par excellence.

SATELLITE PROTECTION

There are various ways of making satellites less vulnerable to ASATs. First, satellites could be promptly replaced when they are destroyed. At present, U.S. satellites are more sophisticated, reliable, and longer lasting than their Soviet counterparts. For example, the newest Soviet photo-satellites have a lifetime of six weeks, whereas that of the U.S. KH-11 exceeds two years. U.S. communications satellites have lifespans five to ten times longer than those of the Soviets. Hence, the Soviets need to replace satellites far more frequently, and this higher Soviet launch rate may grant them a potent wartime reconstitution capability. The United States has now begun to devote greater attention to satellite replacement: for instance, by placing spare satellites in orbit, to be activated when needed.

There are other ways, varying in efficacy and cost, to protect satellites. Attack by a homing ASAT could be frustrated by a satellite that can maneuver, or that can deceive the ASAT's homing device. If there is ample warning of attack, as is true with the current Soviet ASAT, evasion could be commanded from the ground. Against the swiftly approaching U.S. ASAT, evasion would be difficult if not impossible. Radar homing devices of the sort used by the Soviet ASAT could be foiled with jammers placed on board satellites. Infrared homing devices, such as the one on the U.S. ASAT, cannot readily be jammed but could be deceived by decoys deployed by the target satellite. With the exception of photo-satellites, most current satellites have little or no ability to maneuver. But manned spacecraft such as the space shuttle could be used to refuel low orbit satellites, if they were properly designed. This would allow the satellites to carry enough fuel for evasive maneuvering.

It is also possible to achieve some degree of protection against directed energy beams and radiation. Photo-satellites, for example, could be protected against blinding from low-intensity lasers by automated shutters. Electronics can also be hardened against neutral particle beams and nuclear explosions.

If the development of ASATs continues unrestrained, we can expect to see competition between techniques of destroying satellites, and methods of protecting them. Since satellites are inherently fragile and complex, they are virtually certain to lose this competition to simpler weapons whose sole mission is to destroy them. Satellites that have mission lifetimes of many years are particularly vulnerable since they must be equipped with defenses against future, unpredictable, ASAT threats.

THE MILITARY UTILITY OF ASATS

ASATs could be used by the superpowers in a variety of confrontations ranging from wars between their client states, to full-scale nuclear war. Various scenarios can be examined, but because of the number of unknown factors they are necessarily speculative. Indeed, the most serious threats to security are likely to arise from unexpected and unwise actions that may be taken simply because of the existence of an ASAT capability.⁴

Our analysis will distinguish between possible near-term and more distant scenarios. This is a natural division to make because the current generation of ASATs does not threaten higher orbit strategic satellites, while those of the future are likely to do so.

Regional Conflicts

In the past, both superpowers have been very cautious about sharing intelligence data from satellites with even their closest allies, although they have occasionally provided allies with battlefield intelligence drawn from other sources. In 1973, for example, the Soviet Union gave Egypt aerial photographs of Israeli forces on the West Bank of the Suez Canal.⁵ This superpower satellite reconnaissance of Third World battlefields is on its way to becoming a regular feature of international politics, however. Would either superpower deem it in its interest to use ASATs against the other's satellites?

The use of ASATs in such cases seems rather implausible because of the risks of escalation it would entail. Damaging or destroying the other superpower's satellite would almost certainly provoke a serious crisis. Moreover, there are less provocative, more direct, and long-accepted ways to show commitment and offer military assistance—increased logistics support, sending of advisers or even troops, intelligence support from aircraft or other traditional means—if it proved necessary to aid an ally or encourage caution in the other superpower. Unlike the destruction of a satellite, none of these actions involve a direct attack against a military asset of the other superpower.

Superpower War in Europe

That a major war between NATO and the Warsaw Pact would long remain conventional appears to us an illusion. Nevertheless, the superpowers devote the lion's share of their military budgets and training programs to preparations for conventional war. For this reason alone, we must consider the possible utility of ASATs in a conventional superpower war.

Our findings are disquieting. In the near term, neither side is likely to use ASATs because they offer no significant military advantage. In the long term, the temptation to use ASATs will be much greater. The combination of more capable ASATs with greater dependence upon satellites will create strong pressures to use these weapons. Attacks

against satellites would significantly raise the nuclear alert level, producing new and complex interactions between the warning and response mechanisms of the two superpowers. They would also be likely to provoke retaliation in kind, an event that would aggravate the potential for loss of control. It seems that advanced ASATs are a military Pandora's box: at first glance, their use may be appealing, but the consequences may be disastrous.

The characteristics of existing ASATs and those that could be deployed in the next few years severely limit their utility. They cannot make possible a surprise conventional attack in Europe. Any systematic effort to destroy or interfere with intelligence satellites would itself provide relatively unambiguous warning of impending attack. Moreover, since the superpowers also use ground-based and airborne surveillance systems in Europe for early warning and intelligence gathering, simply destroying satellites would not eliminate surveillance capabilities.

ASATs could not deprive either side of theater-wide communications, either. At first sight, the United States has the greater vulnerability in this regard, because it has assigned satellites a primary responsibility for important communications missions, using ground-based systems as a backup. For the Pact, the situation is generally the reverse. Both superpowers have nevertheless built up extensive cable, microwave, and radio communication networks to meet most of their immediate military needs in the absence of satellites. Battlefield communication between different sectors, more heavily satellite dependent in NATO, could also be provided by airborne relays.

Another possible use of ASATs, after the onset of fighting, would be to destroy low-orbit photographic, electronic, and radar surveillance satellites that can enable the other side to locate military units behind the battlelines. Perhaps the most likely scenario for Soviet attacks on American satellites, for instance, would be in the aftermath of a stalled Warsaw Pact offensive. The Soviet high command might be desperate to buy a "window of darkness" behind which to regroup forces and shift the axis of advance, and so be willing to risk the repercussions of initiating ASAT warfare. An action such as this would undoubtedly be part of a coordinated attempt to deny NATO battlefield intelligence from a variety of other sources.

In this connection, it is important to recognize that satellites are likely to play an increasingly important role as sources of battlefield

intelligence the longer any war lasts, due to the likely attrition of more conventional intelligence assets. Even so, ASAT operations are unlikely to deprive NATO entirely of critical military intelligence, even though they could seriously interfere with real-time intelligence gathering. In the absence of low-orbit satellites, NATO would have to rely on intelligence from aircraft, drones, ground-based sensors, and ground observers. Intelligence from such a large number of discrete sources, operated by a variety of different and only partially integrated commands, would take considerable time to collate, interpret, and relay. The resulting loss of real-time capability could severely curtail the effectiveness of NATO air defenses, and significantly affect the course of ground operations as well.

“Sweeping the skies” of low orbit satellites so as to deny surveillance of areas far behind the front would appear to be a militarily attractive objective. But there are other, less risky, ways to hinder satellites. Electronic intelligence satellites could be thwarted by jamming or spoofing, or through encryption of communications. Photo-satellites are often thwarted by the cloud cover in Central Europe, which prevails about 60 percent of the time. In clear weather, aircraft (manned and unmanned) could supply much of the photographic reconnaissance needs, even though such operations could prove costly. Radar surveillance satellites would be the most irreplaceable low-orbit satellite capability. Alternatives, such as airborne radars, must be flown in well-protected airspace and would thus gain only a limited view behind the battlelines. Radar satellites, on the other hand, are likely to be more vulnerable to jamming and spoofing.

The most commonly proposed U.S. anti-satellite use also involves shielding rear area forces: preventing Soviet satellites from tracking NATO’s carrier battlegroups that protect the Airland bridge, which is vital to the reinforcement of Europe. But since the Soviets rely heavily on submarines and trawlers for continuous tracking of NATO naval forces, denying satellite coverage would not protect the ships. In any case, the Soviet ocean radar reconnaissance (RORSAT), ocean ELINT (EORSAT), and photographic satellites used to track NATO naval movements all appear to have significant operational limitations; the Soviets have experienced several failures of the RORSAT and have only once maintained a full constellation of RORSATs and EORSATs.⁶ Given the technical shortcomings of Soviet ocean recon-

naissance satellites, these systems could be defeated by jamming and spoofing, without the need for an ASAT. Yet for NATO to deny ocean surveillance to the Soviets entirely, it would have to clear the seas of Soviet submarines and ships, and also successfully interdict the large number of Backfire bombers used by Soviet Long Range Naval Aviation to provide additional coverage. This would be a formidable task.

Overall, the marginal military utility of the current generation of low-altitude ASATs seems to us unlikely to offset the hazards of their use. The destruction by one superpower of the other's low-orbit satellites could well provoke retaliation in kind, raising the prospect of undesired and perhaps uncontrollable escalation. It is unclear just how much loss of satellite-borne theater command-and-control either side will tolerate, especially if important ground-based facilities are being damaged or destroyed at the same time, before it resorts to graver measures. It is for these reasons that we feel the use of ASAT in any war fought in Europe in the coming years would be counter-productive—a view that we feel would probably be shared by the highest military authorities in both Washington and Moscow.

But if we look ahead to the next decade, the picture is rather different. NATO's vulnerability to Soviet ASATs is likely to increase in proportion to its growing reliance on satellite-based systems for battle management. In coming decades, NATO may have radar satellites for theater-wide surveillance of aircraft. The U.S. Navy may also become increasingly dependent upon satellites to counter stand-off threats to its carrier groups posed by Soviet aircraft and submarines. NATO forces, down to the platoon level, are expected to use Navstar satellites to improve the delivery of firepower. The follow-on-force attack (FOFA) and other deep strike strategies, if they are implemented, would make NATO even more dependent upon low-orbit satellites for locating Soviet second- and third-echelon forces behind the line of battle.

The Warsaw Pact may also become more dependent upon satellites. Some Soviet military writers envisage satellites as the solution to the fundamental dilemma of Soviet conventional strategy: the battle-field responsiveness so essential to the kind of offensives the Soviets contemplate is in conflict with their rigid and hierarchical command structure. A real-time battle management system would permit the Soviet general staff to direct operations with much more flexibility

and responsiveness. If the Soviet Union develops such a capability in the course of the next decade, it could become even more dependent than NATO is upon satellites.

By the 1990s, both superpowers can also be expected to have deployed more capable ASATs, perhaps ones able to destroy satellites in geosynchronous orbits. This would bring about a highly unstable and dangerous situation because both the superpowers would be extremely dependent upon vulnerable satellite systems.

It is conceivable that mutual vulnerability would enhance mutual deterrence and restraint. Fear of escalation could also encourage restraint. An historical parallel might be found during the Korean War when, for both these reasons, the two sides tacitly respected critical sanctuaries throughout the fighting. The United States refrained from attacking the air bases in China from which MiGs sallied forth daily to strike at United Nations' positions. China and North Korea for their part never attacked the American carriers or other warships in Korean waters that provided vital air and naval support for ground operations.

Yet it is also possible that one or both of the superpowers would attack the other's satellites because of their military utility. NATO dependence upon radar satellites would give the Soviets a strong incentive to take out those satellites at the start of their offensive; likewise, NATO will be sorely tempted to attack satellites essential to the Soviets' battle management capability. The need to conduct ASAT operations in order to guarantee victory or to stave off defeat could be seen as so vital at the time that it would seem to offset the risks of escalation. The historical analogy in this instance is to Germany, which during the First World War decided to wage unrestricted submarine warfare. Both the Kaiser and his military chiefs were fully aware of the magnitude of their decision. If the U-boat campaign succeeded, Germany would win the war, and the opprobrium of using such a weapon would be of little consequence. If it failed, as indeed it did, American intervention was expected to lead, in the German chancellor's words, to "*finis Germaniae*."

Which outcome is the more likely, restraint or attack? The greater the asymmetries between satellite dependence and ASAT capability, the more prospects for mutual deterrence will decline. In the opinion of many experts, the United States will maintain a significant advantage in ASAT capability for the foreseeable future. But the U.S.

is also likely to become more dependent upon satellites, and this should reduce the temptation to exploit its ASAT advantage.

The most destabilizing situation would be one in which the superpower with the greater ASAT capability also had the least dependence on satellites. This seems unlikely to occur but it is not entirely inconceivable. By the late 1980s, the Soviet Union could have an operational ASAT against low-orbit satellites as effective as the American ASAT. At the same time, the United States could have become much more dependent upon satellites for the range of military purposes we have described. In such a circumstance, the Soviets might see few drawbacks to using their ASATs.

Nuclear War

Satellites would play a more important role in intercontinental nuclear war than in regional or conventional conflicts because they provide eyes and ears for early warning of nuclear attack, battle management of nuclear forces, and post-attack assessment of nuclear strikes.

American satellites that perform these functions are almost all in geosynchronous or semi-synchronous orbits where they cannot be attacked by the existing Soviet ASAT. Soviet satellites are now somewhat more vulnerable because the Molniya orbits of Soviet early-warning and many communications satellites are, in principle, within range of the current U.S. ASAT weapon. In the future, the development of directed energy ASATs, whether as part of ballistic missile defenses or as dedicated ASATs, could threaten satellites at all altitudes with prompt and simultaneous destruction, carried out at the same time as an offensive first strike.

To some extent, such an ASAT attack could impair the other side's ability to launch a coordinated counterforce strike in response. Nonetheless, our analysis persuades us that directed energy ASATs would not significantly effect the course of a nuclear war *once it has begun*. The real danger is that advanced ASATs would compound the difficulty of *terminating* a nuclear war, and in a crisis they would undoubtedly heighten the chance that nuclear war would break out.

Our judgment about the contribution ASATs would make in a nuclear war stems from several considerations. First, even advanced ASATs would, for the most part, only marginally degrade early-warning capabilities. For the United States, the increment of ad-

ditional warning provided by satellites is important but insufficient to protect the national command authority, submarines in port, and bombers on the ground from destruction by Soviet missiles fired from off-shore submarines. The United States is more vulnerable in this regard than the Soviet Union because of its greater reliance on bombers and submarines as strategic launch platforms. It is nevertheless reasonable to assume that if an intercontinental nuclear war occurs, it will arise out of a serious crisis or war in Europe or elsewhere. American strategic forces would already be on alert and therefore less vulnerable. Contingency arrangements would also have been put into effect to shift the command center away from Washington, thus reducing the likelihood of strategic paralysis in the aftermath of an attack on command authorities.

Given the present situation, loss of early-warning satellites would be more easily borne by the Soviet Union, if only because their systems are less reliable and effective than their American counterparts. The Soviets continue to experience serious difficulties in maintaining an operational constellation of early warning satellites. Even if the Soviets established effective satellite coverage of North America, they would remain vulnerable to nuclear attacks by missiles deployed in Western Europe, and on submarines in the Mediterranean, Arctic Ocean, and, with the advent of the Trident submarine, the Indian Ocean as well. Submarine-launched Trident II missiles, when they become operational, will be accurate enough to destroy Soviet missile silos. Threats of this kind constitute a growing problem for the Soviets, as 75 percent of their MIRVed missiles are land-based, stationary, and increasingly vulnerable. Yet there is nothing to indicate that a U.S. ASAT attack on Soviet early-warning satellites or radars would significantly increase our ability to destroy their ICBMs. Destruction of these systems would in itself constitute early warning and could prompt Soviet leaders to launch their missiles.

In the aftermath of ASAT attacks, both superpowers would also lose important wartime communication capabilities. Here, the United States is probably more dependent on satellites because it uses them to communicate with submarines and airborne bombers. Although these functions could be assumed by ground stations and airborne relays, these systems are themselves highly vulnerable, and cannot be expected to endure very long in a nuclear war.

Both superpowers would presumably also use satellites for post-attack assessment. Since bombers and cruise missiles would reach their targets hours after warheads delivered by missiles, it would be most efficient to assess the result of a missile-delivered attack before following up with other forces. The U.S. government has placed great stress on post-attack assessment in recent years, in keeping with its overall notion of how an intercontinental nuclear war should be fought. The recent emphasis has been on developing the means to fight limited or protracted nuclear wars, despite the widespread conviction among strategists and senior military officers that such scenarios are unrealistic. The Soviets give every indication of sharing this skepticism and, for this reason, may judge post-attack assessment to be relatively unimportant. It also appears alien to their approach to nuclear combat, which emphasizes a massive initial strike, as opposed to a series of strikes, each followed by assessment.⁷ In the case of full-scale nuclear war, both sides' satellites will, in any case, become useless after the first exchange, since satellite ground stations and launch pads will almost certainly be destroyed.

ASATs could both increase the likelihood of nuclear war and complicate its termination. Widespread destruction of communication satellites would make it difficult to restrain one's own forces or to transmit a cease-fire order, reducing still further the possibility of limiting a nuclear war once started. And if there were negotiations to end the war, it would be nearly impossible, without surveillance satellites, to monitor the adversary's behavior and gauge the extent of his compliance with any agreement.

Advanced ASATs could have a dramatic impact on crisis stability. Each side must anticipate that in the event of attack, it would have very little time to assess the threat and select an appropriate response. Laser ASATs, for example, could destroy an entire constellation of satellites almost instantly. Such an ASAT attack could coincide with a first-strike, increasing the risk and fear of "decapitation"—the destruction of a country's political-military leadership. A country could develop contingency procedures to be adopted during such crises, but even though this might reduce the probability of decapitation, it would never eliminate the fears. Policy makers could be stampeded into making these fears of war self-fulfilling.

At high levels of strategic alert, advanced ASATs would exacerbate the inherent instability of the superpowers' command-and-control

systems.⁸ When the alert level of strategic forces is raised, it is necessary to diffuse nuclear launch authority within the military command structure as a precaution against decapitation. However, this heightened alert status would quickly be recognized by the early-warning and response system of the other superpower, which could be pressured into taking similar precautionary action. This feedback loop could progressively dilute centralized control and result in unauthorized actions and inadvertent war. This flaw in command-and-control structures would appear to be an inevitable consequence of the desire to deter a decapitating attack—a situation that would be aggravated by advanced anti-satellite weapons, whose very existence would require a very considerable acceleration of the response tempo.

ASAT ARMS CONTROL

The hazards of escalation or preemption posed by ASATs could be averted by constraining the growth of ASAT capabilities on both sides through negotiated arms control. Such a constraint would also close an important loophole in the ABM treaty.

Unfortunately, the record on ASAT negotiations thus far has been mixed. The United States induced the Soviets to join in several rounds of talks, beginning in 1978, but formal negotiations ceased in 1979 for reasons unrelated to ASAT. Since 1981, the Soviets have repeatedly asserted an interest in resuming negotiations, and from 1983, they have observed a test moratorium. The United States has recently shown interest in negotiating, but insists on continuing the development and testing of its ASAT.

The argument against ASAT arms control was set forth in a report to Congress from the Reagan administration in March 1984. The report contended that the large variety of space systems and activities that have some ASAT capability makes it very difficult to define the term “space weapon” for arms-control purposes; that a truly comprehensive ban on tests of all methods for countering satellites could not be verified; that test bans limited to weapons dedicated to ASAT activities, though perhaps verifiable, could induce the Soviets to develop covertly an ASAT capability that relies on other systems, such as ICBMs or maneuvering spacecraft; that cooperative verification measures might require the United States to divulge sensitive informa-

tion; and that ASAT arms control would not provide protection for satellite ground stations and launch facilities.

The report also argued that there are compelling considerations in favor of a U.S. ASAT capability, quite apart from these arms-control problems. In particular, U.S. ASATs would deter use of Soviet ASATs, and prevent space from being a sanctuary for Soviet satellites that would enhance the capability of their military forces, especially in naval warfare. The report concluded that “no arrangements or agreements beyond those already governing military activities in outer space have been found to date that are judged to be in the overall interest of the United States and its Allies.”⁹

We disagree. A viable ASAT arms-control regime that serves U.S. security interests can be identified. In principle, there are a number of forms that an ASAT agreement might take. The most rigorous would forbid the possession, testing, and use of all techniques that can threaten the functioning or survival of satellites. The least restrictive would not limit ASAT technology, but would only expand the rudimentary body of law that governs space activities. Among the latter are “rules of the road” that would restrict close encounters between space objects of one nation and that of another, or agreements that would outlaw the use of weapons against satellites—not unlike the laws that now apply on the high seas. While such constraints would still leave ASAT weapons deployed on both sides, they merit serious consideration for their ability to prevent inadvertent incidents that might otherwise trigger a crisis or conflict. These provisions could be negotiated in their own right or be included as articles in the treaties we shall discuss below.

A vexing problem for ASAT arms control is that a wide variety of space activities have some ASAT potential. For instance, manned or unmanned maneuvering spacecraft could approach an adversary’s satellite and interfere with it or destroy it. But such “spin-off” ASAT techniques would not pose a prompt threat to a set of satellites dispersed in space, and approaching several satellites simultaneously would constitute warning in itself. From a military viewpoint, this kind of “residual” ASAT capability is likely to be of marginal utility. Furthermore, whatever threat it poses could be reduced (though not eliminated) by formal “rules of the road,” and by measures that allow satellites to assess such threats and evade them by maneuvering.

Another argument against ASAT arms control is that a very potent ASAT capability already exists in nuclear-armed ICBMs, SLBMs, and the Soviets' Galosh ABM interceptors. These, it is asserted, could be used to attack satellite ground stations and spacecraft at virtually any altitude with nuclear warheads. However, using nuclear warheads, even in outer space, is a risky and provocative act, and it is most unlikely that such acts would be committed unless a nuclear war were on the verge of breaking out, or had just done so. Treaties cannot offer protection once the nuclear threshold is crossed; ASAT arms control should seek to make that initial step less likely.

In sum, it is important to distinguish between *dedicated* ASAT systems that can promptly attack a whole set of satellites without resort to nuclear weapons, and *residual* ASAT capabilities in other weapons or systems. We therefore turn to possible restraints on dedicated ASATs.

A treaty that bans possession of all ASATs would be desirable, but compliance would be difficult to verify. The dismantling of readily visible facilities such as the launch sites used for the Soviet ASAT and the U.S. Army's Homing Overlay Experiment could, in principle, be verified. That would, however, be of limited utility, since ASATs could be launched from other Soviet space facilities, and Homing Overlay interceptors could presumably be launched from many U.S. ICBM silos. Even highly intrusive on-site inspection could fail to verify whether these ground-based interceptors were being covertly stockpiled, and possession of the very small F-15 ASAT would be especially difficult to establish.

A more realistic treaty would confine itself to those ASAT activities that are readily verified: ASAT tests and the development and deployment of new ASAT technologies. Such a treaty could still prevent the development of highly capable ASAT systems. An ASAT test ban treaty could be couched in a number of ways: it could forbid the testing of any technique that could prevent the functioning of a satellite, even if it caused no permanent damage. Or it could confine itself to techniques that actually damage the satellite, cause it to change its orbit, or destroy it. In the latter instance, the test ban could either cover all ASATs, regardless of their altitude capability, or only high altitude ASATs.

Activities that could hinder or prevent the proper functioning of a satellite, without causing any damage, are legion. Deception, camou-

flage, encryption, spoofing—all could prevent a satellite from “seeing” or “hearing” what it was intended to see or hear. These activities, however, could not be outlawed effectively. Jamming at an intensity that produced no damage could perhaps be forbidden, though it would be difficult to define unambiguously. Furthermore, jamming, encryption, spoofing, and so on are also benign and valuable countermeasures. For this reason, treaties restricted to acts that produce well defined damage or malfunctioning are to be preferred.

A high-altitude ASAT test ban treaty—one banning tests above 5000 kilometers, for example—at first glance appears very attractive. No dedicated ASAT weapons have yet been tested at such altitudes. The satellites essential to U.S. strategic forces are all at high altitudes, while the Soviet Union could presumably use a combination of geosynchronous and semi-synchronous satellites for such purposes. It would therefore appear that a high-altitude ASAT test ban could “grandfather” the current Soviet and U.S. systems and start with a clean slate, while protecting the most essential military satellites. ASAT tests at high altitudes are also more amenable to verification since they are less likely to be confused with other space activities.

This case for a high-altitude treaty is undercut, though, by the movement toward directed energy weapons, whether for ASAT or ballistic missile defense. A variety of beam weapons could, once they had been tested against low altitude satellites or missile warheads, pose a grave and prompt threat to geosynchronous satellites *without* any testing against high-altitude targets. To be effective, a high-altitude ASAT test ban would therefore have to be accompanied by a ban on directed energy weapons at low altitudes.

An ASAT test ban that covers *all* altitudes therefore provides the most viable and valuable ASAT constraint. By including all ASAT weapons, such a ban would also close the most important loophole in the ABM treaty. The severe strictures on BMD development imposed by that treaty could be evaded by dressing the first phase of a BMD program in ASAT clothing. Indeed, quite apart from any treaty, the kinship between ASAT and BMD techniques, and the great vulnerability of satellites as compared to missiles, make the ASAT route a natural path towards BMD. By the same token, a program that is only intended to produce an ASAT capability could, under many circumstances, be construed by the opponent as a budding and

illegal BMD program. Since the ABM treaty is the foundation on which all strategic arms limitation rests, the prevention of further ASAT competition would strengthen the shaky arms-control edifice.

The Reagan administration has contended that an ASAT test ban treaty is not verifiable. Yet that judgment is disputed by a number of officials who have held high-level positions in intelligence and military space programs.¹⁰ These officials stress that while verification cannot guarantee the total absence of covert testing of single weapons, it would be virtually impossible to test surreptitiously a system of the complexity required for a prompt and reliable ASAT capability. Extensive experience in observing Soviet programs has convinced these experts that the Soviet military would have little confidence in a system that had not undergone realistic tests, and that such realistic tests could not escape detection. Their statements also underline a point that is not often appreciated outside the intelligence community, to wit, that a properly drawn treaty eases the task of intelligence assessment since it dramatically reduces the pace of technological change.

The Reagan administration's pessimism regarding ASAT verification stands in sharp contrast to its optimism over ballistic missile defense. The space surveillance complex that would mastermind the BMD system envisaged by the SDI is supposed to track vast numbers of space objects, discriminate among them, assign interceptors to each, assess the success of intercept, and reassign weapons—all in a matter of minutes. Moreover, it would have to perform these automated functions while itself under direct attack, and in the environment created by nuclear explosions. If such a formidable task can even be contemplated, it is presumably possible to develop a peacetime space surveillance system that would monitor the relatively infrequent and isolated events that are candidates for clandestine ASAT tests, especially as that system need not come to prompt decisions and would involve human beings.

A viable and adequately verifiable test ban treaty *can* be constructed, provided it is focused on the objective of preventing the growth of a *prompt* and *dedicated* Soviet ASAT capability. If the objective is enlarged to encompass a host of secondary concerns raised by systems that have only *residual* ASAT capability, a viable treaty will no longer be possible. One should also recognize that ASAT arms control would be cost-effective. Under unrestrained ASAT

arms competition, we would have to buy far more elaborate space surveillance facilities and satellite defenses—not to mention the ASATs themselves—than under ASAT treaty constraints.

CONCLUSION

Both superpowers are about to make fundamental decisions concerning the military uses of space, decisions that will have far-reaching implications for their security, in the widest sense of the term. Without doubt, their most fateful decision will be whether and how to pursue a space-based ballistic missile defense. Another critical choice they face is whether to continue placing ever greater reliance on military satellites. As satellites grow in military importance they also become more attractive targets. If, at the same time, space-based BMD is allowed to evolve, the capability for satellite destruction will increase dramatically. Unless these conflicting trends are resolved, the superpowers' unending quests for greater individual security will, once again, result instead in a mutual loss of security.

How are we to avoid this outcome, especially given the technologies that can be envisaged? We can do so only by maintaining and reinforcing the goals and stipulations of the ABM treaty. We should accompany this reinforcement with a comprehensive ban on the testing of space weapons, and more ambitious programs to protect satellites. As we have argued above, this is the prudent policy choice, for it recognizes that the space weapons technologies presently under consideration have a considerably greater potential for exacerbating tensions and enlarging conflicts, than they do for bolstering deterrence or improving actual military missions. Under such treaty constraints, the United States would possess much more secure space-based intelligence, early-warning, and command-and-control facilities at considerably lower cost than it would in an environment in which both superpowers were continually refining their ability to destroy satellites.

It must be admitted that a side effect of these constraints would be the creation of a sanctuary in space that will be used to deploy satellites with ever greater military capabilities. Some would argue that such a development is intolerable and therefore unstable. But the alternative—unrestrained militarization of space—is far less tolerable. The superpowers must learn to live with the hazards posed by

relatively secure satellites, for in the nuclear age the prevention of war must take precedence over the ability to wage it efficiently.

ENDNOTES

- ¹For data on Soviet satellite programs, see Nicholas L. Johnson, *The Soviet Year in Space: 1982* and *The Soviet Year in Space: 1983* (Colorado Springs, Co.: Teledyne Brown Engineering, 1983 and 1984); Stephen M. Meyer, "Soviet Military Programmes and the 'New High Ground,'" *Survival*, Sept.-Oct. 1983, pp. 204-15.
- ²For more on the Soviet ASAT test program, see Richard L. Garwin, Kurt Gottfried, and Donald L. Hafner, "Anti-Satellite Weapons," *Scientific American*, June 1984, pp. 45-55.
- ³Testimony by Gen. Lew Allen, Senate Foreign Relations Committee, July 11, 1979.
- ⁴Assessments of future ASAT capabilities are further complicated by the fact that they will depend as much on political choices as they do on technology. In the course of the next few years, both superpowers will have to decide how dependent they wish to become on space-based systems for their military needs, how much money and effort they are willing to spend to protect their satellites or to make them redundant, and of course, what kinds of ASAT weapons they want to develop and deploy. These decisions cannot be predicted with any accuracy.
- ⁵Anwar L. Sadat, *In Search of Identity: An Autobiography* (New York: Harper & Row, 1977), p. 260; Mohammed Heikal, in *The Road to Ramadan* (New York: Ballantine Books, 1975), p. 241, insists that these were not satellite photographs.
- ⁶Naval authorities nevertheless maintain that these satellites give the Soviets an additional important surveillance capability. Louise Hodgden, in "Satellites at Sea: Space and Naval Warfare," *Naval War College Review*, July-Aug. 1984, pp. 31-45, reviews official statements to this effect.
- ⁷Stephen M. Meyer, "Soviet Military Programs and the 'New High Ground,'" *Survival*, Sept.-Oct. 1983, pp. 204-15.
- ⁸Paul Bracken, *The Command and Control of Nuclear Forces* (New Haven, Conn.: Yale University Press, 1983), makes a good case for the likelihood of the national command authority becoming so fragmented in the course of a nuclear war that important strategic decisions might well be made, or even have to be made, at levels several steps or more down from the top.
- ⁹President's Report to Congress on U.S. Policy on ASAT Arms Control, March 31, 1984. According to Leslie H. Gelb in the *New York Times* (Aug. 3, 1984), "important segments of the Navy" do not concur with the report's claim that ASATs are required to counter the threat posed by Soviet ocean reconnaissance satellites, and instead believe that the Navy has more to lose if American communication satellites are attacked than it has to gain by ASAT attacks on Soviet ocean reconnaissance satellites. Furthermore, Gelb reports that "civilian leaders in the Pentagon and the Arms Control and Disarmament Agency have rejected these [military] views and have sustained the [ASAT] program," and that the March 31 report represents a compromise between these conflicting positions of the civilian and military leaderships.
- ¹⁰See R. Jeffrey Smith, *Science*, May 18, 1984, pp. 693-695; the individuals interviewed include Leslie Dirks, until 1982 CIA deputy director for research and technology; Walter B. Slocombe, formerly deputy under secretary of defense;

James Reynolds, former manager of the Navstar program; and Michael May, associate director of Livermore National Laboratory. See also Robert W. Buchheim's May 2, 1984, testimony to the House Foreign Affairs Committee. There has been some concern that ground-based or airborne optical lasers could be developed clandestinely for ASAT purposes. Low-intensity lasers that could swamp a photo reconnaissance satellite, or even damage it, are feasible and would probably evade detection, but it would be a simple matter to equip such satellites with shutters triggered by light sensors. According to Michael May, covert installation of high-intensity ASAT lasers would not be possible.

The Relationship of ASAT and BMD Systems

PUBLIC OPINION AND POLICY LEADERSHIP today insist on merging anti-satellite weapons and ballistic missile defenses under the general rubric of “Star Wars.” But how accurate is it to treat ASAT and BMD as but two facets of a single security problem? At their earliest beginnings more than thirty years ago, ASAT and BMD were treated as naturally related security concerns, for the simple reason that missiles and satellites were both viewed as extensions of the long-range aircraft as a means of strategic attack. But in the intervening decades, ASAT and BMD programs have gone their separate ways. Satellites evolved to carry sensors and radio transponders, not nuclear warheads, while ICBMs have remained faithful descendants of the strategic bomber. ASAT and BMD therefore came to respond to distinct military missions and to pose distinct arms-control problems. There are sound reasons for public policy to treat them separately.

But while their military roles diverged, ASAT and BMD systems continued to share certain technical characteristics, and the argument for merging the two issues focuses precisely on this technological overlap. Because of this overlap, certain types of ASAT systems would possess marginal BMD capability, and many types of BMD systems would have quite substantial ASAT capability. Though this overlap must not obscure the substantial differences between ASAT and BMD, it does give rise to several genuine complications for BMD and ASAT policy. On the one hand, the overlap poses an “ASAT upgrade” problem: unrestrained development or deployment of ASATs having

some BMD capability could circumvent the strict limits on missile defenses in the ABM treaty. On the other hand, imposing restraints on ASAT development could also impede development of advanced BMD technologies (or countermeasures to BMD) at an earlier stage than the terms of the ABM treaty alone would require; this might render comprehensive ASAT arms control incompatible with the Reagan administration's Strategic Defense Initiative (SDI). Proponents of the SDI could, on this ground, be led to oppose ASAT arms control, while critics of the SDI could use ASAT arms control as a political tool to suppress BMD.¹

There are potential hazards in making ASAT and BMD policies hostage to each other in this way. If the policy debate over ASATs is wrongly transformed into a symbolic battle over BMD, we may lose the opportunity to judge the military utility of ASATs and proposals for ASAT arms control on their intrinsic merits. At the same time, some near-term BMD deployment options do not require space-based components, and the merits of these deployments may be overlooked if they are wrongly swept up in the drama over the "militarization of space." One should hope instead for a policy debate that addresses the overlap between ASAT and BMD, while respecting the basic differences between their roles in military security.

DIFFERENCES BETWEEN ASAT AND BMD

In the broadest strategic and military sense, ASAT and BMD have little connection. Ballistic missile defense is concerned with providing protection to the nation in the midst of nuclear war, and its affinities in overall military planning are therefore to air defense, civil defense, anti-submarine warfare, anti-tactical ballistic missile defenses, and other activities that have little or nothing to do with space or with ASATs.

Anti-satellite weapons, on the other hand, might well play a role in nuclear war, but many of the ASAT scenarios cited as worthy of concern have little or nothing to do with nuclear war; they range all the way from peacetime tampering with reconnaissance satellites through varying levels of use in crisis and conventional war. Indeed, ASAT use during nuclear war may not be regarded as the most worrisome use of ASAT, nor, for that matter, one that can be

easily guarded against through satellite defense programs or arms-control agreements.

From the point of view of arms control, ASAT and BMD could scarcely be more different. The ABM treaty imposes firm and comprehensive restraints on BMD, and few question the ability of the United States to detect militarily significant violations of its provisions. Virtually no arms-control limits exist on ASAT activities, however, and many doubt the verifiability of agreements that would seek to eliminate all or most threats to satellites.

The argument that technological advances are blurring the distinction between ASAT and BMD and thus compel us to consider them as a single issue is in many ways overdrawn. It is true that both missions may involve intercepting objects at roughly comparable altitudes and speed. But the visibility and vulnerability of satellites, boosters, post-boost vehicles, and warheads differ somewhat; and satellites may orbit at altitudes many times higher than those reached by ICBMs. Future advances in directed-energy technologies might well bring greater commonality to ASAT and BMD weapons. But some very significant methods for disrupting satellite functions—space mines, attacks on ground stations, deception—have no BMD analogues. And important terminal and mid-course BMD systems now under study have no space-based components and would work at low-orbital or sub-orbital altitudes.

Above all, the performance requirements of effective ASAT and BMD systems are almost incomparable. ASAT attack can be mounted from a friendly country, but BMD interception of ICBM boosters must take place from outer space and over enemy territory. BMDs must handle many targets in a short time, whereas ASATs need engage relatively few targets at a leisurely pace. The ASAT operator picks the timing of attack; BMD must react to the initiative of the offense. BMD must operate in the most hostile circumstances imaginable—in the midst of nuclear war—whereas ASATs are just as likely to be used during crises or conventional conflicts.

In short, while there is little technical difference between the act of destroying a satellite in orbit and the act of intercepting an ICBM in flight, there is an enormous difference between the effective performance of a BMD *system* and an ASAT *system*.

EXAMPLES OF ASAT-BMD OVERLAP

To gain some sense of the balance between their technological similarities and performance differences, it will be useful to compare the capabilities of a few illustrative ASAT and BMD systems that share the same technologies.

Current Soviet ASATs and ABMs

The current Soviet ASAT interceptor is a multi-ton device launched by an ICBM-sized missile into an orbit that crosses the orbit of its target. It is guided in the final moments of intercept by a radar or optical homing sensor. The ASAT bears little or no resemblance to Soviet BMD systems under development, in either hardware or interception technique, and it has no BMD capability.

The Soviet Galosh ABM interceptor missiles deployed around Moscow, and currently being upgraded, can fly to altitudes of up to several hundred kilometers and laterally to comparable distances. Ground radars guide Galosh's ascent until it is close enough to its target, at which point its nuclear warhead detonates. Galosh's multi-megaton nuclear warhead could destroy satellites of today's design at ranges of many hundreds of kilometers. In upgrading the Moscow ABM system, the Soviets are deploying one hundred interceptors in all, some portion of them modified Galosh missiles. Galosh missiles therefore constitute, in principle at least, a potent nuclear ASAT system with several dozen low-altitude interceptors. It is even conceivable that with proper radar and guidance, Galosh could use a non-nuclear warhead for ASAT attacks. (The remainder of the upgraded Moscow ABM interceptors will be shorter-range missiles with little or no ASAT capacity.)

Current U.S. ASATs and ABMs

The U.S. homing vehicle ASAT, which would be launched by an F-15 and is undergoing testing, and the Army's Homing Overlay BMD device both involve guiding a small space vehicle to the vicinity of its target with a long-range sensor, activating an infrared homing sensor as the vehicle draws nearer to its target, and destroying the target by direct impact. The Army's Homing Overlay test of 1984, in which an ICBM warhead was intercepted and destroyed, demonstrated that objects at altitudes of several hundred kilometers and at near-orbital

speeds can be intercepted by such homing devices. This homing technology is therefore clearly applicable to both ASAT and BMD, if matched to the proper boosters and integrated into an overall system.

If the United States were to deploy a BMD site consisting of a hundred Homing Overlay interceptors (the number permitted under the ABM treaty), together with appropriate radars or other long-range sensors, such a system would be capable (generically, at least) of making large numbers of low-altitude ASAT intercepts within a short time. Since the Overlay interceptor missile's range is envisioned to be long enough to allow BMD coverage of much of the continental U.S. from a central launch site, the Overlay system would not have to wait for satellite ground tracks to pass very near to the launch site to make ASAT intercepts. The system would therefore make intercepts within at most a few hours of receiving an attack order. On the other hand, this BMD system would threaten only low-orbit satellites.

The U.S. homing vehicle ASAT, as currently conceived, probably has no capability whatsoever to intercept missile warheads launched from the Soviet Union. Among other reasons, the long-range sensors that provide guidance for the ASAT mission (the spacetrack network of ground-based radars, which include the early-warning radars along U.S. borders) are probably inadequate for ICBM intercept, and communicating their data to the ASAT interceptor's guidance system in a timely manner is also probably impractical.

But let us suppose that the United States or the Soviet Union were to deploy an ASAT system consisting of homing vehicles such as those now being tested by the U.S., based not on F-15s but on ground-launched missiles capable of reaching high altitudes. Suppose appropriate long-range sensors for these ASAT interceptors were also provided. The small number of interceptors deployed for an ASAT-only mission—perhaps less than a hundred—would clearly not constitute a major BMD system. A system designed as an ASAT, and not adapted to the stringent requirements of BMD, would also be susceptible to the usual panoply of BMD penetration aids and countermeasures, including nuclear attack on its components. Seen from this point of view, such an ASAT system would seem to be an insignificant missile defense.

From another point of view, however, even this limited BMD potential could not be entirely neglected. A hundred long-range ASAT interceptors of this sort could defend the entire country against small

attacks. Even against large attacks, preferential defense tactics would allow either superpower to ensure with high probability the survival of a small number of selected targets. It is precisely the possibility of employing limited ASAT systems in such ways that gives rise to the "ASAT upgrade" issue. This issue will be treated in further detail below, but from this example it is already clear that one's concern over ASAT upgrade is determined more by strategic outlook—whether the survival of a few selected targets makes a critical difference in strategic stability—than by technical details.

Space-based lasers

This discussion will confine itself to orbiting chemical lasers, but most remarks apply as well to orbiting particle-beam weapons. Here, the ASAT potential of a good BMD system is quite clear. If a space-based laser BMD system had the beam brightness and number of orbiting battle stations required for effective BMD, and if its sensors could be adapted to the task of finding satellites as well as missiles (probably a minor matter), it would be capable of instantaneous attack on satellites at all altitudes. Even against heavily shielded satellites, the laser beam could presumably dwell on the target long enough to cause damage.

A space-based laser system designed specifically for the ASAT mission, on the other hand, would probably consist of a smaller number of orbiting stations of lesser beam brightness and smaller fuel supply, since the total number of targets to be attacked would be fewer, and the time available longer, than for the BMD task. Moreover, an ASAT system would presumably not be designed to withstand very vigorous BMD penetration tactics. Both sides could easily calculate the potential of such an ASAT system to intercept ICBMs and SLBMs. The space-based laser ASATs would be able to intercept a small number (let us say fifty) of simultaneously launched ICBMs; it could intercept a larger number if the ICBM launches were spread out in time, permitting each laser to turn to new targets when finished with the first wave. In contrast with the previous case, a space-based laser ASAT of this sort would *not* have the capability for preferential defense of a few selected sites, since it would intercept ICBMs in the early stages of flight before they revealed their intended targets. However, a space-based laser ASAT could completely interdict small nuclear attacks (fifty missiles, in this case), thus forcing an

attacker to mount far larger attacks or to employ special penetration aids for which the ASAT was unprepared. Once again there is a potential ASAT upgrade issue, depending on one's strategic outlook.

Ground-based lasers.

A ground-based laser BMD system would require much greater beam power than its ASAT counterpart, since its energy would have to be transmitted over longer ranges (up to an orbiting mirror and then back down toward the earth) and destroy its target as rapidly as possible. Such a BMD system would be able to attack satellites directly if they passed over its ground site, or destroy them over the horizon if its orbiting mirrors could be oriented for ASAT attacks.

A ground-based laser ASAT system would not require orbiting mirrors to redirect the beam, though such mirrors might in fact enable the system to attack a satellite without waiting for it to pass overhead. (An orbiting mirror would also permit use of adaptive optics to compensate for degradation of the laser beam as it passed through the atmosphere.²) Without mirrors to bend its beam around the earth, such an ASAT would clearly have no BMD capability, and even with mirrors its beam would not be powerful enough for BMD if originally designed only for the ASAT mission. A ground-based laser ASAT could be a way station en route to a BMD capability, however, allowing tests of basic techniques that could later be scaled up to BMD requirements. The U.S. SDI program will reportedly follow this route in its investigation of excimer lasers.³

X-ray lasers

X-ray lasers, powered by nuclear explosions, could be stationed in space, but they are also light and compact enough to be employed in a "pop-up" mode in which the weapons would be rapidly launched into space when needed. An orbiting X-ray laser would display much of the same ASAT-BMD interaction as the space-based chemical lasers described above.

A pop-up X-ray laser BMD system deployed by the U.S. near Soviet borders in order to intercept ICBMs (probably a quite impractical approach), or along U.S. coasts to intercept Soviet SLBMs, could clearly double as an ASAT system. The missile carrying the laser device would merely need to climb above the atmosphere (or to an

altitude where the X-ray beam could “bleach” its way through the upper atmosphere) and detonate, destroying any satellite within its—potentially long—range and line of sight.

An X-ray laser would have an advantage over an ordinary ground-launched direct-ascent ASAT interceptor since it would not need to ascend all the way to its target to destroy it. Because X-ray lasers would be powered by nuclear explosives detonated in space, however, they would be appropriate for ASAT use only in extreme circumstances when breaching the nuclear threshold was thought acceptable. Such a pop-up laser ASAT deployed on U.S. soil would have no capability to intercept ICBMs ascending from the Soviet Union, since it could not attain line-of-sight altitude to the ICBMs before they burned out. On the other hand, such a system might have limited use in intercepting SLBMs launched from near U.S. coasts, thus raising again, in a very constrained form, the ASAT upgrade issue.

Sensors

Like the weapons themselves, the sensor systems that support BMD and ASAT systems can serve a dual purpose. In the past, the tracking of ICBM warheads for BMD has been performed by ground-based radars, at least some of which would also be capable of tracking satellites at lower altitudes. This tracking data would allow the ASAT to plan its attack and to respond to the launch of a new satellite within several orbital revolutions. Conversely, radars built for space-tracking can also track ICBMs. However, to avoid ambiguity, a nation can locate its space-track radars in places inappropriate for BMD (for instance, beyond national borders or along the nation’s periphery and facing outward).

The U.S. has considered replacing or augmenting its space-track radar network with a Space Surveillance and Tracking System (SSTS) consisting of satellites with infrared sensors able to distinguish space objects as warm spots against the cold background of space. Such sensors would be able to track not only satellites but also ICBM warheads and post-boost vehicles, and they are in fact under investigation in the SDI. For the BMD task, such sensors would have to be able to detect and keep track of thousands or tens of thousands of targets instantaneously and to discriminate missile warheads from decoys. For the ASAT task, it would be sufficient to be able to track

fewer targets and to discriminate over a longer period of time. But it may be difficult for either side to judge, when looking at the other side's sensor systems, precisely what their capacities are.

If such sensors are able to track ICBMs "in flight trajectory" with enough precision to support a BMD mission, they might qualify as "ABM components" under the terms of the ABM treaty. If so, deployment of SSTs for ASAT support would violate the treaty's ban on space-basing of ABM components. A similar problem to ASAT-BMD overlap has already arisen with the case of the Soviet radar under construction at Krasnoyarsk in the central Soviet Union. The Soviets claim the Krasnoyarsk radar is for space-track only; the U.S. points out that the radar's inherent BMD capability (however limited) was precisely the reason the ABM treaty required that such radars be deployed only on the Soviet periphery. Further issues of ASAT-BMD overlap could emerge with the use of other types of sensors, such as space-based radars, laser radars, and satellites with short-wave infrared detection sensors.

A number of general principles emerge from this brief review of ASAT and BMD technologies. An efficient BMD system could, with little or no effort, be made a potent ASAT, though in some cases with only limited altitude capability. A system designed specifically for the ASAT mission, on the other hand, generally would be a poor BMD. However, in many instances the technology itself would not distinguish between the two missions in a way that would make possible a clear judgment that an ASAT system had *no* BMD capability. Actual ASAT and BMD systems might in fact have particular limitations resulting from details of their design that would prevent or constrain dual use. But such detailed limitations might not be visible to another nation's intelligence analysts. Finally, even the rather limited BMD capacity of dedicated ASAT systems might be viewed as strategically significant by one side or the other. It is from these complications that the ASAT upgrade issue arises.

THE ASAT UPGRADE ISSUE

Early BMDs evolved out of surface-to-air missile (SAM) systems used for intercepting bombers. From the start, there was concern that SAM systems might be upgraded to enable them to intercept missile

warheads as well as aircraft. Since missile warheads travel twenty or thirty times faster than aircraft and have much smaller radar visibility, missile defense requires better radars, faster data processing, and faster interceptor missiles than air defense.⁴ The SAM systems use the same type of components—radars and interceptors—as BMD systems, and it is possible that these interceptors might, in the right circumstances (such as being equipped with nuclear warheads), be capable of intercepting missile warheads. Particularly susceptible to interception are those warheads with low reentry speeds, such as older models and some submarine-launched models. By deploying SAM systems with BMD potential, a superpower could circumvent the limits of the ABM treaty. The treaty's litmus test for SAM upgrade is whether the SAM system has ever been tested against strategic missile warheads. Such testing "in an ABM mode" would qualify the SAM as a BMD for treaty purposes.

American concern with SAM upgrade began with the Soviet SA-5 in the 1960s and continues today with the SA-10 and SA-12. Over the years, the Soviets have improved the capabilities of their SAMs to keep up with improved U.S. bomber capabilities. At the same time, U.S. missile warheads have grown faster and harder to detect. Despite their ability to intercept certain U.S. missile warheads under some conditions, Soviet SAMs are clearly not designed as BMDs, and *as systems* their BMD potential is extremely limited. In general, their radars cannot search for missiles at long range over wide sectors of the sky, do not seem to have the data processing capability to handle large numbers of warheads quickly, cannot discriminate warheads from decoys, and their interceptors cannot handle modern fast warheads and certain reentry angles. All in all, the effectiveness of Soviet SAMs against U.S. missile attacks would be marginal.

Nonetheless, there have sometimes been reasons why SAM upgrading has seemed more plausible than it needed to be. In some early U.S. ICBMs, for example, the warhead and upper booster stage flew close to one another, allowing a relatively unsophisticated Soviet radar to use the large upper stage as a locator.⁵ Also, it is of little comfort to point up a Soviet SAM's susceptibility to penetration aids such as decoys if the United States has not incorporated such aids in its offensive planning. What is more, there are circumstances (at least according to some analysts) in which the ability to intercept a few U.S.

warheads would be significant if it could give the Soviets a virtual guarantee that a few selected targets in their country would survive.

The analogous ASAT upgrade issue stems from U.S. fears that the Soviet Union might deploy a system nominally intended for ASAT use, but in fact capable of BMD. Even if they did not deploy such a system, the Soviets might develop advanced BMD technology in the guise of ASAT development, preparing for “leakout” or “breakout” from the ABM treaty. By testing against orbiting objects but not against missiles “in flight trajectory,” the Soviets could seek to evade the treaty’s strictures on BMD development. ASAT activities that pressed upon the edges of the ABM treaty would cause both sides to hedge their bets against surprises by pushing forward their own programs. A spiral of mutual fear and suspicion might ultimately erode whatever arms-control relationship the two sides wished to preserve.

A future ASAT upgrade issue would probably recapitulate the SAM upgrade problem. As in the SAM case, no one would claim that if one set out to design ASAT-only and BMD-only systems from scratch that the two *system* designs would have much in common, although individual components might use similar technologies. At issue instead would be the strategic significance of an ASAT’s limited BMD capability, and this in turn would depend more on the observer’s broad strategic outlook than on technical details. To those convinced that the ability to deliver large numbers of nuclear warheads to the Soviet Union is sufficient to assure deterrence, a Soviet ASAT’s modest BMD capability would be meaningless, even in a case where U.S. retaliatory forces had already been reduced by a Soviet first strike. To those convinced that the ability to assure destruction of selected military targets is essential to deterrence, however, even minor Soviet interference with U.S. missile attack plans would be unwelcome. Opinion would differ even more over the extent to which Soviet ASAT work would prepare them to develop truly effective BMD and place them in a position to circumvent or abrogate the ABM treaty. Anxious observers would point to common components—weapons and sensors—while doubters would point to the very different system requirements of ASAT and BMD.

To illustrate these ambiguities, we will consider two hypothetical examples of ASAT upgrading, one of U.S. and one of Soviet deploy-

ment. These examples are purely illustrative, and are not judgments or predictions about the actual future of ASAT upgrading.

Example 1. The United States deploys an ASAT system consisting of fifty land-based missiles carrying infrared homing vehicles. The ASAT system uses data from ground-based radars and from a Space Surveillance and Tracking System (SSTS) to select targets and to guide the homing vehicles to their vicinity. The United States tests its system extensively against a variety of orbiting targets, but never against sub-orbital objects.

The Soviets worry that these fifty interceptors could be used against missile warheads. Fifty warheads is a small fraction of a Soviet arsenal of thousands. But with its interceptors, the United States can try to preserve a handful of targets selected secretly from the large number targeted by the Soviet Union—a few airfields capable of servicing U.S. airborne command posts and bombers, a ground-command post, an antenna for communication with strategic submarines, a satellite ground station, a radar, a few Minuteman missiles outfitted with radios for broadcast of launch orders. This preferential defense is a substantial annoyance to Soviet planners, since they must now target several warheads at every target they wish to be confident of destroying, and the United States can virtually assure the survival of a small number of carefully chosen targets (by using all fifty interceptors to defend ten sites, for instance).⁶ In small or selective Soviet attacks, the relative effect of a small U.S. BMD capability would be greater still.⁷

Adding another twist to this example, suppose the United States now tests from the Kwajalein Atoll (the terminus of the western ICBM missile test range) a BMD interceptor using a different booster from that used by the ASAT system, but with a very similar homing vehicle. Fixed, ground-based radars provide long-range data to guide the BMD interceptor to its target, but the SSTS gathers data in an adjunct mode during the tests. The Soviets protest that the fifty-missile ASAT system has, in effect, now been tested “in an ABM mode” as well. They assert that since the SSTS might be used to replace, rather than supplement, the ground-based radars, this test violates the ABM treaty’s ban on space-based sensors. The United States rejects this interpretation, and deploys 150 more ASAT inter-

ceptors. The United States also maintains the industrial capability to produce more homing vehicles, prompting Soviet fear of a U.S. BMD breakout. The Soviets, hedging their bets against this possibility, consider deploying more ICBMs, penetration aids, and their own BMD.

Example 2. The Soviets launch a space structure combining a moderately powerful chemical laser with a large mirror. They test destruction of satellite targets, using a long-wave infrared SSTS and possibly laser radars to direct the laser beam. Eventually a total of ten such lasers appear in orbit.

The United States realizes that these laser satellites could attack ICBM and SLBM boosters and post-boost vehicles, even though the lasers are a hundred times less capable than would be required to handle simultaneous launch of hundreds of U.S. ICBMs. The Soviet lasers can therefore destroy, let us say, between ten and one hundred U.S. ICBMs boosters in a U.S. missile attack. The United States does not wish to go to the cost and trouble of countering the Soviet lasers with specialized penetration tactics. The Soviet lasers threaten a larger fraction of U.S. SLBMs, since SLBMs are spread over wide ocean areas where they are subject to attack by many orbiting lasers. Against a U.S. ICBM force reduced by a Soviet first strike, the Soviet protection is greater still. However, the Soviet lasers cannot accomplish the preferential defense that the U.S. ASAT in the previous example was able to accomplish, since the precise destination of U.S. missiles is not apparent during their boost phase. The Soviet lasers can also attack British, French, and Chinese missiles, creating great concern in these nations.

Over the years, the Soviets replace their early versions of these laser satellites with new models. U.S. intelligence cannot estimate precisely the output of the factories that make the lasers, the unit costs, or the characteristics of future models. U.S. intelligence also cannot determine whether inactive Soviet laser satellites that remain in orbit are capable of reactivation. The Soviet lasers have never been tested against strategic ballistic missiles "in flight trajectory," but they have been tested against a variety of orbiting targets. The Soviet Union has also performed, in other space programs, pointing and tracking experiments on ballistic missiles.

The United States considers survival of the Soviet lasers in wartime intolerable and makes contingency plans to attack them with ground-based lasers.

These examples, though somewhat fanciful, demonstrate the potential for a real ASAT upgrade dilemma. Doubters can always claim that a nation intending to use its ASAT for BMD would only be able to intercept a fraction of opposing missiles. Yet others worry that even a modest capability could be useful against SLBMs, against third powers, and against ICBMs in some scenarios; that the defense's capability poses an especially alarming threat to a retaliatory force that is reduced and disorganized by a first-strike attack; that the offense will not, in fact, deploy penetration aids that could overcome the defense; or that breakout or further upgrading is imminent.

ASAT ARMS CONTROL AS AN IMPEDIMENT TO BMD RESEARCH

A second aspect of ASAT-BMD overlap involves possible arms-control agreements. The ABM treaty permits research and restricted development of BMDs. Both nations value this latitude to seek more effective BMD concepts and to hedge against unexpected activities by the other side. In the United States, the Reagan administration has made such research a major part of its Strategic Defense Initiative. ASAT arms control might increase the limits on BMD-related activities and impede progress of the SDI.

One can think of a few explicit cases of conflict between possible ASAT bans and useful BMD development activities. For instance, the ABM treaty permits the United States to test-launch interceptors from Kwajalein against missile warheads. Such a test system might well be considered a low-altitude ASAT, even if it were never tested against orbiting objects. An ASAT treaty intending to ban low-altitude ASAT capabilities would either have to ban such tests or draw a dubious distinction between intercept of orbital and sub-orbital objects. To take another example, suppose the United States wished to develop powerful ground-based lasers and associated adaptive optics to investigate their BMD potential; an ASAT treaty might prohibit propagation of high-energy laser beams from the ground to orbiting

targets. The extent to which ASAT bans would actually impede BMD research that is genuinely necessary to explore the technology's potential would obviously depend on both the details of an ASAT treaty and the degree to which BMD researchers are able to maneuver around treaty limitations.

Perhaps the main impediment that ASAT arms control presents to the SDI is political rather than technical. Public debate will very likely construe even carefully delimited ASAT negotiations as applying to all space weaponry, and will interpret U.S. participation as an implicit commitment to tone down the national initiative on BMD. Proponents of ASAT arms control will advertise their wares as a tool to combat the SDI, even though the ABM treaty already places thoroughgoing limits on deployment and on many types of development of advanced BMDs. Opponents of the SDI might be led to support ASAT arms-control negotiations they otherwise would not attach much importance to.

ASATS AS COUNTERMEASURES AGAINST BMD

If ASAT technology has much in common with that of advanced BMDs, it is even more directly linked to advanced offense, that is, to countermeasures against defensive systems. All advanced BMDs envisioned rely on weapons or crucial sensors based in space. ASAT attack on these components is probably the cheapest and most effective offensive countermeasure.

Since the signing of the ABM treaty, the United States and the Soviet Union have conducted penetration-aid research as a hedge against breakout, as a challenge to their own BMD R&D programs, and as a continuing demonstration of the treaty's underlying principle—that confident and cost-effective defense of their national territories is not possible. This research, it is widely agreed, strengthens both sides' confidence in the treaty.

If aggressive BMD research programs proceed, both sides will presumably wish to develop and test ASAT interceptor missiles, space mines, and directed energy weapons that could be used against BMD battle stations. Limitations on testing and deployment of ASAT, by depriving the two sides in some measure of the opportunity to demonstrate their ability and determination to counter defenses, might have the paradoxical result of increasing the two nations'

fear of breakout, and might even tempt them to initiate deployment of BMDs that could not survive ASAT attack.

FOUR FUTURES

The importance of shared ASAT-BMD characteristics and functions depends largely on the future course of legal restrictions. There are four conceivable ways in which arms-control limits on BMD and ASAT systems could be combined: 1) the status quo, with an ABM treaty and no ASAT treaty; 2) an ABM treaty plus an ASAT treaty; 3) an ASAT treaty but no ABM treaty; and 4) no limits on either ASAT or BMD systems. Quite apart from the intrinsic merits and demerits of ASAT and BMD arms-control limitations, it would appear that in all four combinations the overlap of ASAT and BMD will give rise to problems and inconsistencies.

1) ABM treaty; no ASAT treaty.

The most important issue in this case would be whether unrestrained ASAT activity would ultimately erode the ABM treaty. ASATs tested solely against orbiting objects would not fall under the treaty's defining criterion, since they would not be tested against ballistic missiles in sub-orbital flight. Both sides could thus test space-based, mobile, and other ASAT components that are technically akin to BMD components, circumventing the treaty's ban on all but fixed, land-based, radar-plus-interceptor BMD systems. Actual deployment of ASATs that possessed the potential for upgrading to partial BMDs would create further anxieties. If the SAM upgrade precedent is any guide, debate in the United States over the threat of Soviet ASAT upgrading will turn less on estimates of the technical capability of the Soviet ASAT to intercept missiles than on the strategic significance of the modest BMD potential of the ASAT.

Though the technical requirements of effective ASAT are much less challenging than those of effective BMD, there seems to be no legal formulation that distinguishes between the two missions so as to dispel all ambiguities.⁸ In an amicable period of U.S.-Soviet relations, regular discussions might temper the disruptive effects of these inevitable ambiguities. But it would not be easy in the best of climates to strike a constructive balance, in the United States at least, between

a willingness to tolerate some ambiguities and a determination to challenge Soviet behavior that surpasses comfortable bounds.

2) ASAT treaty and ABM treaty

Supposing the United States and the Soviet Union wished to limit ASATs, managed to satisfy verification requirements, and found enough common ground to proceed to agreement; they would still have to accept the fact that ASAT limitations will constrain their BMD research programs. If the ASAT treaty forbids test interception of orbital objects, for instance, can it tolerate the tests against suborbital objects explicitly permitted by the ABM treaty? Even if the ASAT negotiations handle the technical ambiguities in such a way so as to minimize interference with BMD research, political opinion in the United States is very likely to view the spirit of the ASAT treaty as obliging the United States to scale back its Strategic Defense Initiative.

3) ASAT treaty but no ABM treaty

For obvious political reasons, collapse of the ABM treaty seems unlikely to coincide with wide-ranging ASAT arms control. But even if compatible politically, unrestrained BMD is incompatible technically with a comprehensive ASAT ban since almost all types of truly effective BMDs would also be overwhelmingly powerful ASATs. On the other hand, some observers imagine a time when both sides cooperate in limiting ASAT activity during or after deployment of advanced space-based BMDs, peacefully ushering in a defense-dominated world. One may doubt the plausibility of this political vision, but it is logically possible.

4) No arms control

If enthusiasm for technical advances or snowballing political misunderstandings lead the two superpowers to abandon the ABM treaty, there will no longer be any question of the legal compatibility of their ASAT and BMD programs. The technical outcome of this future is uncertain, but it is possible that potent ASATs would drive BMD deployment from space, and that other military support missions heretofore conducted from space (communications, reconnaissance and surveillance, navigation, meteorology) would have to find

more survivable backups. In such a world, space would be ASAT dominated, and strategic warfare would remain offense dominated.

*

*

*

Although there is as much perception as reality in the overlap between ASAT and BMD, the reality is nonetheless palpable and unavoidable. It grows out of certain inherent technical similarities between the two types of systems, to which is added a strong (if not always well-informed) popular identification of ASAT and BMD as one and the same “Star Wars” vision.

But in fact ASAT and BMD systems respond to fundamentally different security concerns. ASATs challenge the rather paradoxical proposition that space—alone among earth, sea, and air—should be a sanctuary in which satellites can conduct a wide range of military activities, such as surveillance and navigation, free from fear of destruction. BMD concerns itself with only one military contingency—the ultimate contingency of nuclear war—and with the proposition that the imperfect defenses which it is within technology’s power to build can contribute to avoiding such an event.

Until public policy settles on an answer to these two propositions separately, a policy for managing their overlap will continue to elude us. Indeed, discussion of the subject both in the U.S. and in the 1985 Geneva arms-control talks seems to be taking an opposite path, considering ASAT and BMD precisely in their region of overlap. To do this risks forfeiting judgment of each on its own merits, while at the same time making resolution of one dependent on resolution of the other. Only when we have clear policies on ASAT and on BMD individually will their difficult area of overlap prove tractable.

ENDNOTES

¹These issues have been raised previously in a similar vein by Donald M. Kerr, “Implications of Anti-Satellite Weapons for ABM Issues,” paper prepared for the SIPRI Symposium on “Outer Space: Can Militarization be Checked,” Stockholm, Sept. 21–23, 1983 (Los Alamos report LA-UR-83-2455 [Rev]):

Without an ASAT Treaty, development and deployment of directed energy ASAT technology would offer a severe challenge to the present ABM Treaty regime, as well as posing potentially serious new realms for military

competition and threatening one of the key stabilizing and limiting mechanisms between the superpowers. On the other hand, the negotiation of a restrictive ASAT treaty, because of the substantial intermingling of ASAT and ABM technologies, might pose insurmountable obstacles to the development of many of the most promising BMD technologies.

²See Ashton B. Carter, *Directed Energy Missile Defense in Space* (U.S. Congress, Office of Technology Assessment, April 1984), Chap. 3.

³Clarence A. Robinson, Jr., "BMD Research Draws Strategic Focus," *Aviation Week & Space Technology*, June 18, 1984, p. 83.

⁴See Stephen Weiner, "Systems and Technology" in *Ballistic Missile Defense*, ed. Ashton B. Carter and David N. Schwartz (Washington D.C.: The Brookings Institution, 1984) pp. 73-74.

⁵See Sayre Stevens, "The Soviet BMD Program in Carter and Schwartz, op. cit., p. 206.

⁶See Ashton B. Carter, "BMD Applications: Performance and Limitations," in Carter and Schwartz, op. cit., p. 104 and 150ff.

⁷See "Defense Against Ballistic Missiles: An Assessment of Technologies and Policy Implications," (Department of Defense, April 1984), containing conclusions of the Future Security Strategies Study headed by Fred S. Hoffman.

⁸A strictly legal distinction could be based on ASAT intercept of *orbiting* objects and BMD intercept of objects on *suborbital* trajectories that intersect the earth's atmosphere. Whether a space object intercepted by one side in a test was on an orbital or suborbital trajectory would be easy for the other side to determine. The ABM treaty defines a BMD as "a system to counter strategic ballistic missiles or their elements in flight trajectory." A corresponding ASAT treaty could refer to "space objects in stable orbits." The legal distinctions would then be clear: a system never tested against suborbital objects (i.e., "never tested in an ABM mode") would not be subject to ABM treaty limitations, and a system tested only against suborbital trajectories would be immune from ASAT treaty restrictions (since it was never tested "in an ASAT mode"). While this distinction is legally neat, technically unambiguous, and easy to verify, few would accept that an extensively tested BMD had no ASAT capability and vice-versa. As always, it is the *capability* of a system, and not its nominal or declared purpose, that must form the basis of treaty definitions.

Notes on Contributors

Hans A. Bethe, born in 1906 in Strasbourg, France, is Professor Emeritus of physics at Cornell University. A Nobel laureate in physics, Dr. Bethe was director of theoretical physics for the Manhattan Project during World War II. He has written widely on defense and technology issues and is a consultant to the Los Alamos and Lawrence Livermore Laboratories.

Jeffrey Boutwell, born in 1950 in Boston, Massachusetts, is a staff associate at the Committee for International Security Studies of the American Academy of Arts and Sciences, and adjunct research fellow at the Center for Science and International Affairs, Harvard University. He is the author of *Nuclear Weapons and the German Dilemma* (forthcoming from Cornell University Press) and co-editor of *The Nuclear Confrontation in Europe* (Croom Helm, 1985).

Ashton B. Carter, born in 1954 in Philadelphia, Pennsylvania, is assistant professor of public policy at the John F. Kennedy School of Government, Harvard University, and assistant director of the Kennedy School's Center for Science and International Affairs. Dr. Carter is co-editor of *Ballistic Missile Defense* (1984), and the author of "MX Missile Basing" and "Directed Energy Missile Defense in Space" for the Office of Technology Assessment, U.S. Congress.

Alexander Flax, born in 1921 in New York City, is President Emeritus of the Institute for Defense Analyses in Arlington, Virginia. Dr. Flax formerly served as the Air Force's chief scientist and assistant secretary for research and development.

Richard L. Garwin, born in 1928 in Cleveland, Ohio, is an IBM fellow at the Thomas J. Watson Research Center and holds teaching and research positions at Columbia, Cornell, and Harvard Universities. Dr. Garwin served on the president's Science Advisory Committee from 1962 to 1965 and from 1969 to 1972. Formerly a member of the Defense Science Board (1966–1969), he has been an active consultant to the U.S. government and its agencies since the 1950s.

Kurt Gottfried, born in 1929 in Vienna, Austria, is professor of physics at Cornell University. A member of the board of directors of the Union of

Concerned Scientists, he has served on the High Energy Physics Advisory Panel of the Department of Energy and the National Science Foundation.

Donald L. Hafner, born in 1944 in New York City, is associate professor of political science at Boston College and has written extensively on arms control and anti-satellite weapons. As a member of the U.S. Arms Control and Disarmament Agency in 1977–78, he served as an adviser with the U.S. SALT Delegation in Geneva and as an analyst with the National Security Council's SALT and ASAT Working Groups.

Richard Ned Lebow, born in 1942 in Budapest, Hungary, is professor of government and director of the Peace Studies Program at Cornell University. Dr. Lebow was professor of strategy at the U.S. National War College, and formerly scholar-in-residence at the Central Intelligence Agency. He is the author of many books and articles on international politics, most recently, *Between War and Peace: The Nature of International Crisis* (1984).

F. A. Long, born in 1910 in Great Falls, Montana, is Professor Emeritus of Chemistry and of Science and Society at Cornell University's Program on Science, Technology, and Society. He was the assistant director for science and technology of the U.S. Arms Control and Disarmament Agency and participated in the 1963 negotiations in Moscow that resulted in the 1963 Limited Test Ban Treaty. He is the editor of *Arms, Defense Policy, and Arms Control* (1975), *The Genesis of New Weapons: Decision Making for Military R&D* (1980), and *Appropriate Technology and Social Values: A Critical Appraisal* (1980).

Paul Stares, born in 1955 in London, England, is a research associate at the Brookings Institution. Formerly a Rockefeller International Relations and NATO Fellow, he is the author of several books including the upcoming *The Militarization of Space* (1985). Dr. Stares is co-editor of *The Exploitation of Space* (1985).

Gerold Yonas, born in 1939 in Cleveland, Ohio, was director of pulsed power sciences at Sandia National Laboratories, Albuquerque, New Mexico, and a member of the Defensive Technologies Study Team established to advise President Reagan on strategic defense initiatives. Shortly after writing this article for *Daedalus*, Dr. Yonas was appointed chief scientist of the Strategic Defense Initiative Organization at the Department of Defense.

Herbert F. York, born in 1921 in Rochester, New York, is director of the Institute on Global Conflict and Cooperation at the University of California, San Diego, where he is also a professor of physics. A former

member of the president's Science Advisory Committee and former Defense Department official, he served as the chief negotiator on the 1963 Limited Test Ban Treaty as well as participating in the delegation on anti-satellite arms control with the Soviet Union, 1978–1979.

Charles A. Zraket, born in 1924 in Lawrence, Massachusetts, is executive vice president and chief operating officer of MITRE Corporation, in Bedford, Massachusetts. He is also a trustee of the Hudson Institute, a member of the board of overseers for the Center for Naval Analyses, and consultant to the Department of Defense. His most recent publication is "Strategic Command, Control, Communications, and Intelligence," *Science* magazine (June 1984).